Final Report

Power from the Sun: An Evaluation of Institutional Effectiveness and Impact of Solar Home Systems in Bangladesh

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M. Asaduzzaman
Mohammad Yunus
A. K. Enamul Haque
AKM Abdul Malek Azad
Sharmind Neelormi
Md. Amir Hossain

Bangladesh Institute of Development Studies

E-17 Agargaon, Sher-e-Bangla Nagar

Dhaka 1207, Bangladesh

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LIST OF ABBREVIATIONS

ADB	Asian Development bank
BDT	Bangladesh Taka
BIDS	Bangladesh Institute of Development Studies
EU	European Union
GIZ	German Development Cooperation
GPOBA	Global Partnership for Output Based Aid
IDB	Islamic Development Bank
IDCOL	Infrastructure Development Company Limited
KFW	Kreditanstalt fűr Weideraufbau
KgOE	Kg of oil equivalent
PO	Partner organization
PV	Photovoltaic
SHS	Solar Home System
Wp	Watt-peak

EXECUTIVE SUMMARY

In recent years, Bangladesh experienced more than 6 percent annual rate of growth in GDP. Rural poverty has fallen substantially from 40% in 2005 to 31.5% by 2010 with major gains made by hitherto lagging regions. Such positive changes have, however, been not matched in a commensurate manner in the consumption of energy, particularly electricity. The overall incidence of electrification for households is 55% for the nation as a whole but much lower for rural areas at only 42.5%. Among others, a major reason had been a limited progress towards generation of power till date including the limited nature of power sector reforms that has been attempted. Lack of generation has also thwarted the earlier efforts at reaching electricity to rural areas through the Rural Electrification Board. One solution, possibly a stop-gap one, is to supply electricity through solar photovoltaics.

The sun remits two types of energy, light and heat. Both may be utilized directly for lighting and heating, or indirectly by converting them into electricity, which may then be supplied to entities such as households or firms to be utilized as they see fit. Bangladesh being a tropical country receives plenty of bright sunshine throughout the year and the potentials for use of solar energy has been deemed very substantial. For the time being it may simply be noted that one particular technology, solar photovoltaic system, has become popular the world over for providing electricity to households and enterprises in remote and off-grid areas. Bangladesh is no exception where nearly 2 million solar home systems (SHS) have already been installed by a company called the Infrastructure Development Company Limited (IDCOL) and its collaborating organizations called partner organizations (POs) on the ground.

Several development partners have supported the program so far. They include the World Bank, German Development Cooperation (GIZ), Kreditanstalt für Wiederaufbau, meaning Reconstruction Credit Institute of Germany (KfW), EU, ADB, IDB and a multi-donor trust fund administered by the World Bank—Global Partnership for Output Based Aid (GPOBA).

Despite the fast expansion so far no more than 10-12% of the off-grid households have access to the SHS. That means there are theoretically enough scope for its expansion, particularly given that supply of grid electricity at present faces many constraints including capacity shortages, high cost of fossil fuel, and lack of finance while the demand for electricity is rising due to increased income, urbanization and other factors. How to reach electricity to people, even if in a limited manner, while demand is increasing thus becomes a challenge to policy makers, particularly when the estimated potential size of the market for SHS under certain plausible assumptions is very large (see later).

Given that a substantial number of SHSs have been installed and that the generation and distribution of electricity in the normal process is hampered by many factors making access to it by the vast majority of people uncertain in the near to medium future, policy makers may look towards the expansion of SHSs as a means of reaching power, albeit in a limited way, to the households and people in off-grid areas who are without access to electricity. For this, one must know how effective *the technology had been so far in its reach, to whom and how effectively in terms of serving the needs of the people (by raising the quality of life and welfare as well as meeting electricity needs for directly productive purposes, wherever applicable). The cost, management, technical support and quality of providing the service and how far the present system of financing, management as well as the observed impacts also need to be explored.*

The immediate impact of installing a SHS on the rooftop of a house is to have light after dark, make study easier in the evenings, allow people to watch TVs and be informed of many useful and socially desirable things that are happening around them and be inspired to take part in such activities, lower the indoor pollution levels and even earn some money by renting mobile phone charging services. Solar electricity also has possibly the positive externality of substituting fossil fuels for generation of electricity and thus contributes to lowering of emission of carbon dioxide and the positive consequences in terms of climate change.

The SHSs are costly and also there are problems of management of a decentralized technical system on a one to one basis between service provider on the ground (POs) and the client (household or enterprise). Also, the present SHS capacity may not be able to meet the full demand of the client for various energy services. The present study attempts to unbundle these issues as far as possible based on a large scale survey of beneficiary households as well as service providers at various levels including how the financing mechanism may influence these elements and how some of the technical challenges are being resolved.

The specific objectives of the present study are to find out the following based on intensive empirical investigation and consultation with concerned people:

- *characterization of the SHS adopters and non-adopters;*
- *various impacts, direct and indirect, on the households and its members including those on women;*
- *the nature of the technology and its technical and management limitations on the ground;*
- *the nature and quality of program delivery system and its differentiation by the supplier (POs);*
- *market characteristics, present size, present limitations and future potentials in terms of size given various factors influencing the market;*
- *the role of financing mechanism including subsidy in diffusion of SHS, willingness to pay and subsequent welfare implications for the client.*

To fulfill the objectives of the study, apart from the use of secondary level information, consultation has taken place with IDCOL and the various POs. More importantly, a large household survey among SHS adopters and non-adopters, a survey of field offices of the POs and a community survey have been conducted with pre-tested questionnaires. The total number of households that have been surveyed in 128 villages (64 treatment or supplied with SHS, 64 control without such supply) was 4000 (1600 SHS adopter households in treatment villages, 400 non-adopter households in treatment *villages and 2000 non-adopter households in control villages). The population for the sample of households was the records of the IDCOL on which villages it has supplied SHS through POs and to whom. The villages and households were chosen at random.*

Apart from the usual descriptive analyses of household members including women, several analytical techniques have been used to process various sets of data. These include econometric exercises to analyze factors that influence decision to install a SHS and the size of the system, propensity score matching analyses with adopters and non-adopters in the same village and non-adopters in control villages to understand the impact of the SHS, a simulation analysis to understand the potential size of the market in future for specific capacities of SHS and another simulation exercise to understand the willingness to pay and implications of various financing mechanism involving the subsidies (level including zero subsidy).

Based on various analyses the findings of the study may be grouped as follows:

Present status of SHS diffusion: By December 2012, more than 1.7 million SHSs have been put in place by IDCOL and its POs. The information indicates that just one PO, the Grameen Shakti, accounted for 58% of the SHS that have been installed. Three more POs viz. RSF, BRAC, and Srizony Bangladesh had installed respectively 15%, 6% and 4% of the SHS. By divisions, the percentage distribution was Dhaka: 26, Chittagong: 19, Barisal: 19, Khulna: 11, Rajshahi: 14 and Sylhet: 11. Even though, one may find a skewed distribution by POs, distribution by division is not that uneven although Dhaka and Chittagong are the divisions served most by grid electricity.

Present financing system: The SHS program in Bangladesh is now the fastest growing program, thanks partly to the financing mechanism in place. IDCOL gets the funds from various development partners and then disburses it to the POs based on their expansion schemes. POs are provided several incentives in the form of grants and refinancing by IDCOL for the credit given to households for buying the SHS on installments. The POs get refinancing from IDCOL only after SHSs are installed by them at the households. POs also make a contribution of their own in providing credit while they receive an institutional development grant. Households make down payments as well as installments. POs receive the credit from IDCOL at 6% rate and pay back in 6-8 years. Households pay 12% interest and pay back in 3 years. On the other hand, the grants POs receive have been declining (the program started in 2003 with a subsidy of Euro 90 per system, which has come down to $25 per system by December 2012).

Characteristics of sample areas: In terms of nature of physiography, available education, health, transport, financial services and water and sanitation facilities, there are no major differences between treatment and control villages.

Diffusion of SHS among sample households: The diffusion level of SHS is nearly a quarter or one-third. Barisal rates high on the weighted scale at 48% adoption rate with Sylhet following at 34%, the lowest being in Khulna (neighboring division of Barisal) at 11%.

Characteristics of households: The adopter households have been found to be systematically different from non-adopter households both in the treatment and control villages. Female headed households *are more prominent among adopters compared to non-adopters while age of household head has little overall influence. Household size and age, however, are of not much importance.*

Adopter household heads, however, are better educated as more than 40% have secondary level education or beyond while the proportion is only half of that among non-adopters. An interesting finding is that women's education may have a positive role as among adopter households 76% has at least one woman who has completed primary level education while 20% has women with secondary complete education. For non-adopters the proportions are 60 and 10% respectively.

Non-agricultural occupation is predominant among adopter household heads. On the other hand, the land holding is also much higher among such households. The average land holding are 245 and 209 decimals for total and agricultural land among adopters. For non-adopters these are only about half or less.

Clear differences in level of income are observed. Adopter households have on an average Tk. 160,000 (more or less US$ 2000) per year. This is 80% more than the annual household income of the non-adopters. Much of this difference may be attributed to differences in non-agricultural income than agricultural income. While agricultural income of the adopters is about 33% higher than that of the non-adopters, non-agricultural income is almost 100% higher for the adopters.

Self assessed food security is much higher among adopter households, around 40% of whom consider themselves to be in surplus category while the percentage for non-adopters are only half as much. The adopters' possible future income may also be higher as they spend 50-80% more for children's education than non-adopters.

On the whole the adopters are better endowed with assets and income as well as education. The econometric analyses carried out in the study confirm that this to be true even when other factors are controlled for.

The partial analyses using the above factors did not allow us to examine the independent effects on actual choice to acquire/buy an SHS. Econometric analyses indicate that variables such as total annual income, education of head of the household, non-agricultural occupation, women's education and whether the household has a woman as its head do positively and statistically significantly influence the choice of installation of a SHS.

The system capacity: The SHSs are differentiated, among others, by their capacity to produce electricity and are calibrated in terms of watt-peak (Wp). The POs offer various capacities of SHSs. Of those supplied by them, only three categories of capacity predominate, 20 Wp (24%), 40/45 Wp (21%) and 50/55 Wp (31%). Among these, the 50/55 Wp appeared to be most dominant historically followed by the other two categories. Over the last one year, however, it appears that the 20 Wp category is gaining popularity (particularly because of the introduction of LED based lighting system that can serve the lighting needs of the households with the smaller capacity systems).

Characteristics of SHS in adopter households: These are shown in the table below.

Some Pertinent Information on Sample SHS

Indicators	***Information***	***Comment***
POs from which bought	*GS: 70%; BRAC: 6%; RSF: 7%; Srizony 3.7%; Others: 13.6%*	
Mode of purchase	*99% on credit*	
Price	*From BDT 12489 (20 Wp) to 40911 (85 Wp)*	
Loan duration	*3 Years: 91% of cases*	
Interest mode	*Flat rate: 86% of cases*	
Delayed payments	*436 (27%) cases*	*116: Once; 112: twice; 208: 3 or more times*
Capacity	*20 Wp: 18%; 40 Wp: 21%; 50 Wp: 34%; 65 Wp: 12.4%; 85 Wp: 6.1%*	
Vintage	*78% less than 3 years; 22% more than 3 years*	
Lighting points	*2-5 points: 93%*	*2 points: 23%; 3 points: 27%; 4 points: 31%; 5 points: 12%*
Kitchen lighting	*40% of households*	*20 Wp: 15%; 40 Wp: 36%; 50 Wp: 41%; 65 Wp: 64%; 85 Wp: 71%*
Operating instructions provided	*56% yes; 44% no*	
After sale service agreement	*92%*	*82% given service upon call; 75% within 1-2 days of call*

The above table clearly indicates the following:

i. *Most SHS have been purchased on credit from Grameen Shakti while 3 or 4 other POs are also somewhat important but they are far behind;*

ii. *Only a few categories of SHS capacity predominate. The 50 Wp is the median choice (of one-third of customers), but newer ones are likely to be more in 20 Wp category.*

iii. *Some 78% of SHS have been purchased only over the last 3 years and many since over 2 years or less;*

iv. *Costs vary by capacity, but higher capacity ones may be slightly cheaper on a unit Wp basis;*

v. *While the interest is at a flat rate and the loans are for 3 years mainly, some 27% has delayed payments, among them roughly one half delayed payments for 3 installments or more;*

vi. *Number of lighting points varies by capacity and mostly the use is for 2-5 lighting points rising steadily as the capacity increases with 2 points for 20 Wp and 6 for 85 Wp. Further,* *most interestingly, 40% of SHS households have lighting in the kitchen and that tendency is positively related to the capacity one uses.*

vii. *While proper instructions have been claimed to have been provided on the operation of the SHS to one or more of household members, the proportion of households who claimed to have so received was rather poor at 56%.*

viii. *After-sales services agreements exist in most cases and services are provided mostly within 1-2 days of a call.*

Factors behind choice of capacity: Four economic indicators have been used to find out the relationship regarding choice of capacity of SHS. These are total land holding, agricultural land holding, total value of assets (including financial assets) and total household income per year. The indicators clearly show that the demand for and use of higher capacity SHS is positively related to all of them. The pattern gets stronger beyond the basic low capacity SHS, namely 20 Wp and 40 Wp.

Several social indicators were also used such as age of household head, education, women's education, occupational categories of household head etc. There was no uniform pattern in most cases. In certain cases the relationship appears to be more of an inverted U-shape with the apex being at the 50 Wp category which is understandable given the overall importance of this category of SHS. However, with the recent prominence of smaller capacity systems, this relationship is likely to change in the future.

An integrated econometric analysis was carried out including some of the variables discussed above. Income, household head's education, women's education, and household head's involvement in non-agricultural occupation influenced the decision in favor of a higher capacity, but which PO they bought from did not.

Energy consumption: The households irrespective of the SHS status are dependent on kerosene and biomass for their energy requirement. About 80% of the households use fuel wood or non-fuel wood biomass for cooking and related activities. While 62% of the SHS households reported to use kerosene, the incidence is significantly higher at 99% among the non-SHS households.

But SHS households because of their better economic status may consume more energy on the whole. They consume about 64 kgOE/month of energy from fuel wood vis-à-vis 51 kgOE/month for households without the SHS. Similarly, SHS households consume 62 kgOE/month of energy from non-fuel wood biomass vis-à-vis 65 kgOE/month for households without the SHS. However, it may be noted that ownership of the SHS replaces consumption of fossil fuel (kerosene) among the SHS households (discussed later). The difference in the level of consumption is statistically significant. As the overall consumption of energy does not differ significantly, one can surmise that the use of SHS changes in the composition of energy consumption.

There is a positive correlation between the size of the system and the number of lights that it supports; while only 2 light bulbs are used in a 20 Wp size as many as 6 light bulbs are used in case of an 85 Wp size of SHS as indicated earlier. Further, about half of the households use electricity from the system to run a black and white TV. It was found that energy consumption from the SHS *increases with the size of the land holdings, one of the prime indicators of wealth in the rural Bangladesh.*

How much kerosene is actually replaced in SHS households because it is not used anymore for lighting services? The actual difference on kerosene use on average between an SHS user and non-user is 3.67 liters per month per household and translates into more than 88 million liters per year at the present level of diffusion of SHS.

Gender dimensions of apparent impacts: Two types of issues are important in terms of gender dimensions. First, how SHS installation is affected by gender related variables and second how SHS installations in turn affect women as opposed to men. It has been found that female-headed households are comparatively more likely than male-headed ones to adopt/buy an SHS. On the other hand, presence of educated women in the family, even if it is up to primary level does positively, independently and statistically significantly influence SHS adoption as well as choice of higher capacity SHS.

In terms of the processes and impact, kitchen lighting is more prevalent among female-headed households (50% compared to 40% in male-headed households) while the sense of security is also much higher among women in SHS households.

Both male-headed and female-headed households acknowledge the positive role of SHS in facilitating children's education (54.7% for male-headed and 62.5% for female-headed). Interestingly, respondents from female-headed households (87.5%) are willing to buy another SHS because they think it gives them comfort in their lives, whereas only 45.3% members from the male-headed households consider this as an important factor to decide for another SHS. However, none is willing to acquire an additional unit because of its potential for higher income.

Socioeconomic impact of SHS: The identification of the causal effect of SHS requires an econometric application of a method that helps identify what would happen to the differential socio-economic outcomes between SHS adopters and non-adopters if adopters did not adopted SHS. The application of a propensity score matching (PSM) that matches the adopters with the non-adopters based on the observed characteristics shows that SHS is improves household welfare in a variety of ways. Children's study time increases with SHS adoption, more so for girls than for boys. Girls' study times in the evening increased by 12.1 minutes per day on average compared to 8.5 minutes for boys. Although there is no significant positive effect of SHS on contraceptive prevalence rate, adoption of SHS is found to have a negative effect on recent fertility. Also SHS is found to influence positively women's mobility, general and economic decision-making including purchase of household goods. Women are found to use more time for tutoring children, watching TV, socializing, visiting friends and neighbors with the adoption of SHS that also allows them to run a black and white TV. The disease prevalence has significantly reduced among SHS households. Greater awareness through greater connectivity to TV coupled with better indoor environment (replacing kerosene lamps) may have contributed to lowering the prevalence of diseases.

Operations on the ground: The impacts discussed above are based on what has happened so far and institutional set ups on the ground had a lot to do with it. But will this remain so in future? The overall impression one gets by analyzing the first hand information is that there is an almost standardized system of operation on the ground. Many of the rules and procedures are rather similar across POs. So far it has worked fairly well. But with the rapid growth of the SHS program, POs are operating in areas where others are also operating, the competition is getting tough. Instead of providing quality service, the tendency overall appears to be to compromise with it. This is evident from the performance indicators in more recently set up branches. PO branch officials themselves complain of poorer quality of SHS and its components while consumers also are blamed for some of the problems as roughly a quarter do not properly understand the operation of SHS. As a result, there had been voluntary return and also delinquency due to financial constraints and these are now beginning to accumulate to some extent. As Bangladesh has a very high potential for further expansion of the system, it is high time that before scaling up, the problems should be managed well and not allowed to fester, If it does, again a very good Bangladesh initiative will falter as did several other institutional good experiments earlier such as the Comilla model or the early LGED initiatives.

Nature of demand, role of incentives and size of market: Several interrelated issues have been investigated to find out how the market for SHS behaves and what that means in terms of market operation and market size of SHS. First, it has been found that while on average the demand for SHS is price inelastic (elasticity is -0.85), the elasticity is different at different prices. Up to Tk. 21,500 it is inelastic but becomes elastic beyond that. For example at Tk. 33,000, the elasticity is –1.53.

Given the price elasticity and other factors, the willingness to purchase falls as the Wp rises. Thus, while the overall probability of purchase at current prices is only 32%, for Wp 20, it is 62% which progressively falls to 11% for Wp 65. This happens because the welfare implication for the household as measured by consumer surplus falls almost monotonically.

The changes in the present incentive structure or its changes may have major negative impacts either on household's financial burden or profit for POs. Simulation shows that if IDCOL grant is reduced to zero, average price to households increase but PO's income may also fall which may sway them to sell either on cash or raise rates of interest. If the IDCOL's refinancing percentage is lowered (from the current level of 70% for larger POs and 80% for smaller POs), expected rate of interest for households will have to rise for POs to continue in business. For drop of refinancing, for example, from 80% to 40% will raise the rate of interest charged to households to 24% while an absence of refinancing will raise it to 36%. The changes in the duration of loan from 3 to 6 years lowers the rate of interest to 6% from 12% but the households end up paying almost double the money as interest.

Lowering rate of interest charged to households will lower the total interest payments by households but also lowers the profit of POs. They may thus demand lowering the rate of interest charged to them by IDCOL. Simulation indicates that POs would expect a 1.2% drop of IDCOL rate of interest to POs for every 1% drop in interest rate charged by POs to households.

Finally, by way of illustration, for a SHS unit of Wp 20, if the both grant and IDCOL's refinancing provision is withdrawn, the expected impact will be both on price and on interest rate. The interest rate will rise to as high as 36% (from 12% at present). However, for the given interest rate, the price (take home) will increase by 16% and total payment will increase by 65%. The rate of return to POs will drop and to compensate for that the final impact will be an upward pressure on the interest rate.

The market size simulation shows that under the prevailing system of incentives and prices and assuming that no grid expansion takes place, the markets for SHS by capacity are 5.2 million, 4.8 million, 4.3 million and 3.7 million for Wp 20, 40, 50 and 65 respectively. But as acquisition of one unit usually precludes the purchase of another, under the prevailing circumstances, perhaps the total market size may be around 5 million. But of course, the technical management quality will have to be improved while new technology may have inroads and destabilize the market. Further, part of the market will be ultimately lost to grid extension in the future. Yet, in the foreseeable future, there should not be much of a problem with SHS expansion.

All these need to be assessed against the benefits that the households have received so far. based on a 2 million SHS installed so far, the households have benefited to the tune of more than Tk. 11 billion in the form of consumer surplus. Whatever is done, the benefits to the households, and poor at that in many cases including women, whose welfare will be at stake if financial mechanisms are changed without serious review.

Technical quality of service: Many POs reported major problems in operation of SHS but more than one half (55%) were allegedly due to mishandling by households. On the other hand, practically all POs reported problems of quality with major components of the SHS such as lights/bulbs (74%), charge controller (96%) and battery (69%). On the other hand, just about half of the clients never return damaged or inoperative batteries to the POs.

Of the SHS users in the sample, very few have reported problem regarding the PV panels that required replacement, or needed major or minor repair works. Comparatively more required replacement of their batteries (11%) while a similar percentage of clients reported need for minor repair works. For the charge controllers, 14.0% of the clients have had their charge controllers replaced due to damage/breakdowns whereas, very few needed any repair works.

While available data could not clearly identify whether the batteries or charge controllers were replaced within their warranty period, for some of them, it could be clearly ascertained. Thus, for batteries, the proportion of households needing replacement was 10.1% for SHS installed during the last five years i.e., within the warranty period. For those who installed more than 5 years ago, the proportion was 19.6%. But this latter figure is difficult to interpret and cannot be directly compared to the more recent installations. Similarly for charge controllers, replacements should not generally occur within 3 years of installation. But we find that households needed replacements in 11.4% cases of recent (i.e., installed within last three years prior to survey) installations and in 24.5% cases for those installed more than 3 years before. These figures do indicate that some of the batteries and charge controllers have either been of low quality or that their operations were not proper.

Way forward

As most indicators have shown, the SHS have been accessed mainly by the more affluent sections of rural society. And most have been installed comparatively recently. Yet one finds commendable direct and indirect impacts in terms of education of children, women's empowerment, fertility decline, and control of disease prevalence as well as lowering of kerosene use with its possible concomitant impact on indoor air pollution and lowering of emission of carbon dioxide.

Should the SHS program continue? There is still a vast theoretical scope for raising SHS connection up to at least twice the present market size, but this will have to be carefully assessed if the present incentives structure is further liberalized or tightened. If poorer sections are to be brought into the fold of SHS, the incentives may need to be liberalized. If budgetary considerations predominate, POs' operations may be somewhat less regulated while they may be allowed to sell in grid areas for which there appears to be some demand due to poor quality of grid-based electricity supply. But that may mean more burdens for households. The options are not easy, therefore.

Given these issues, there are a lot that the POs will have to do and the IDCOL as the overseer will have to ensure such behavior by the POs. The following recommendations may be of use for further up-scale and providing better services:

a) *IDCOL should strengthen its quality control and inspections to ensure the quality issues of recent installations do not go beyond control. IDCOL and POs should invest more in technician training to ensure quality installations. IDCOL's efforts of establishing photovoltaic testing facility in Bangladesh should be expedited so that the quality of the SHS components can be tested. Technical audit by independent third parties should be more rigorous and more frequent to detect problems early and appropriate follow-up measures by IDCOL to be ensured to address the problems.*

b) *POs and the IDCOL should decide together how female-headed households and women in general may be provided more access to SHS and its services. Trainees may be chosen as Grameen Shakti does from among women for assembling/servicing SHS components (charge controllers) and thus be a source of income and empowerment for them. An on-going evaluation of women integration into the Grameen Shakti should be able to provide more precise recommendations on this issue.*

c) *The IDCOL should be continuously on the lookout for better and tested technology which minimizes maintenance problems while may provide cheaper alternatives to present models for at least the same energy services compared to previous larger capacity models. The Wp choice based on price, technology and demand from buyers should coalesce together to this end. The IDCOL may review these issues periodically.*

d) *How far subsidy may be changed or withdrawn should be based on assuring POs a healthy return on their investment without burdening the consumers with high rates of interest.*

"Timir Bidari Udar Abhyuday, Tomari Howuk Joy"

Hail the Sun whose ascent pierces darkness all around

(Literal translation of the Bengali verse by Nobel Laureate Rabindranath Tagore)

PROLOGUE

Sun light and heat have been directly used for energy services since ancient times. The benefits of solar energy have been recognized also in literature since time immemorial. The verses in the *Rigveda* of the Aryans hail the Sun as the epitome of life. In modern times too this role has been recognized as the verse from Tagore quoted above testifies.

The transformation of solar heat and light into usable electricity has, however, been of rather recent origin. The large scale use of such transformation of solar energy into power is even a more recent phenomenon. In Bangladesh, this began only a few years ago and by December 2012 more than 1.7 million solar home systems (SHSs) have been installed. Despite various problems - technical, managerial and financial - SHSs now have a firm root in Bangladesh and are poised for taking a real flight upwards as positive technological and management changes are taking place while the beneficial impacts for the targeted clients are real and significant, if not astounding. This has been made possible by efforts at various levels and fronts of action.

From the beginning the diffusion of SHSs was based on a business model in which the partner organizations (POs) of the main domestic sponsor, the Infrastructure Development Company Limited (IDCOL), sell, install and provide backstopping services. The POs were and are provided incentives to be in the business through provisions of various grants and subsidies a part of which they were expected to pass onto the household clients in the form of subsidized credit. Such subsidies provided the initial incentives for the POs to sell as well as the households to buy the new technology. Indeed, as the story unfolds in various chapters in this report, there is a strong case for continuing with the subsidy as solar power is still a costly technology to be affordable to the poorer segments of the population. So read on this saga of SHSs in Bangladesh.

CHAPTER 1

INTRODUCTION

1.1 Preamble

In recent years, Bangladesh experienced more than 6 percent growth in GDP. Rural poverty has fallen substantially from 40 percent in 2005 to 31.5 percent by 2010 with major gains made by hitherto lagging regions (BBS, 2011, p. 61). Such growth and its positive beneficial impacts, have, however, not been matched in a commensurate manner in the consumption of energy, particularly electricity. The overall incidence of electrification for households is 55% for the nation as a whole but much lower for rural areas at only 42.5 percent (BBS, 2011, p. xix). There are several reasons behind the lackluster growth, a major factor being the limited progress towards generation of power till date including the limited nature of reforms[1] that has been attempted.

1.2 Electrification and Role of Solar Home Systems

Earlier ideas related to serving the present off-grid areas by the solar home systems (SHSs) had been that the expansion of the grid-based rural electrification will ultimately take care of such lack of access. Unfortunately the problem of power generation has thwarted such attempts. In addition, grid electricity may not be cost effective in many remote areas in this riverine country. In any case, the overall access has not been high while on the other hand the beneficial impacts of grid electricity on household welfare, and impetus to directly productive activities in the area of commerce, industrial activities, and irrigation had been somewhat limited due to lack of access and reliability of grid supply.

The general lack of access to electricity imposes limits to the prospects of growth and increased welfare as the positive relationship between electrification and growth is well-known in the literature and has also been investigated in the Bangladesh context.[2] It is also generally well-known that access to electricity raises household welfare in several ways.[3] Besides, it should be kept in mind that access to electricity itself is a major indicator of progress in achievement of the Millennium Development Goals (MDGs). The continued rise in the access to electricity, therefore, should be a major development target on counts of growth, increased welfare and quality of life as well as achieving the MDGs. The pertinent question is: if the rate of growth in generation of electricity is slow, and the pace of rural

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[1] For a description and analysis of the current situation, see Asaduzzaman and Ahmed (2009). For a slightly dated but still useful analysis, see Asaduzzaman and Billah (2009). For an analysis of the reform process and the governance problems of the sector see Asaduzzaman (2008).

[2] For example, the long-run elasticity of growth with respect to electricity has been found to be 1.73 by Asaduzzaman and Ahmed (2009).

[3] For details see Asaduzzaman, Barnes and Khandkar (2009).

electrification and its quality is lackluster at best, what may be the way out. Herein lies the importance of the SHS.

The sun remits two types of energy, light and heat. Both may be utilized directly for lighting and heating, or indirectly by converting them into electricity which may then be supplied to entities such as households or firms to be utilized as they see fit. Bangladesh being a tropical country receives plenty of bright sunshine throughout the year and the potentials for use of solar energy have been deemed to be very substantial (Islam, Islam and Rahman, 2006). Not just that, there are also ideas that the solar electricity may actually be supplied through the normal grid (Hossain and Islam, 2011). For the time being it may simply be noted that one particular technology, solar photovoltaic system, has become popular the world over for providing electricity to households and enterprises in remote and off-grid areas. Bangladesh is no exception where nearly 1.7 million SHS have already been installed by December 2012 by a company known as the Infrastructure Development Company Limited (IDCOL) and its collaborating organizations called partner organizations (POs) on the ground. But even such an expansion has resulted in probably no more than a few percentage points of the off-grid households being provided with the system. That means there are theoretically enough scope for its expansion, particularly given that supply of grid electricity at present faces many constraints including power generation constraints, high cost of fossil fuel, and lack of finance while the demand for electricity is rising due to increased income, urbanization and other factors.[4] How to reach electricity to people, even if in a limited manner, while demand is increasing thus becomes a challenge to policy makers. Among others an effort is made in this report to estimate the potential size of the market for the SHS under plausible assumptions and show that the theoretical limit of the market is roughly ten times of what it is now.

Given that already a very substantial number of SHSs have been installed and that power generation and grid network is hampered by many factors making access to it by the vast majority of people uncertain in the near to medium future, policy makers may look towards the expansion of SHSs as a means of reaching power, albeit in a limited way, to the households and people in off-grid areas. For this, one must know how effective the technology had been so far in its reach, to whom and how effectively in terms of serving the needs of the people (by raising the quality of life and welfare as well as meeting energy needs for directly productive purposes, wherever applicable). The cost, management, technical support and quality of providing the service also need to be explored.

[4] The Constitution of Bangladesh (clause 16) treats access to electricity as a basic human right.

The immediate impact of installing an SHS on the rooftop of a house is to have light after dark, make study easier in the evenings, allow people to watch TVs and listen to radios and be informed of many useful and socially desirable things that are happening around them and be inspired to take part in such activities, lower the indoor pollution levels and even earn some money by renting mobile phone charging services.

The SHS also has another positive externality. As sunlight and heat is renewable, and provided by nature, its supply is free while it imposes no environmental burden. Indeed, the more it is used for electricity generation, the more the dependence on fossil fuel falls with consequent lowering of emission of carbon dioxide and the consequences in terms of climate change.

The SHS is not expected, however, to resolve all problems of electrification. It has its limitations, one being the generally high financial cost but also managing a technique on a one to one basis between service provider (POs) and the client (household or enterprise). The third problem is that the capacity of present models of SHS limits the use of electricity mainly to a few types of energy services, not as much as people would like to use them. The present study attempts to unbundle these issues as far as possible based on a large scale survey of beneficiaries as well as service providers at various levels including how the financing mechanism may influence these elements and how some of the technical challenges are being resolved.

1.3 Objectives of the Study

The specific objectives of the present study are to find out the following based on intensive empirical investigation and consultation with the concerned stakeholders:

- various impacts, direct and indirect, on the households and its members;
- the nature and quality of program delivery system and its differentiation by the supplier (partner organizations);
- market characteristics, present size, present limitations and future potentials given various factors influencing the market;
- the role of financing mechanism including subsidy in diffusion of SHS, willingness to pay and subsequent welfare implications for the client.

To fulfill the scope of the study therefore necessitates the examination of several types of issues and decide upon the research questions based on the various elements and their interactive nature. The next sub-section details these issues. Insofar as one has to naturally describe and analyze the relevant aspects of the SHS in detailing the scope, the system is not described separately as such.

1.4 Scope of the Study and the Research Questions

1.4.1 Broad Issues of Impact on Households

Several packages of the SHS are on offer to the clients for installation. A household or any other entity purchasing the system from a PO may choose from packages ranging from 10 to 130 Watt-peak (Wp). The most popular one till recently has been the 50/55 Wp SHS can be used for lighting, charging of electrical appliances like mobile phones, charger lights, etc., as well as for running a radio and a black and white TV. In a typical case, solar powered lights usually replace kerosene lamps or lanterns of various types. The most primitive of these traditional lighting devices is a *kupi* (a one-wick lamp) used mostly in poorer households and also used by women in the kitchens. Not only the *kupi* emits heavy soot inside the house as well as cause de-coloration of ceiling, walls, and other materials exposed to its surroundings, it also provides the dimmest of light. In general, the replacement of the kerosene lamps will reduce indoor air pollution and thus generates health benefits for the household; in particular it may benefit the women and the children more who spend most of the time within the house. Therefore, the replacement of *kupi* compared to other kerosene lamps like lanterns may also be more pro-poor as well as being more gender-friendly.

The major difference among the different packages of the SHS is in terms of number of connection points used mainly for lighting. The more points there are the more are the substitution scopes away from kerosene. On the other hand, the higher packages on offer are costlier and may be demanded mainly by the comparatively well-off households. This creates hypothetically a differentiation in impact across households ranked by economic condition (wealth, assets, income, etc.). One needs to understand if this is the case; and if there are such differentials in impact, how pronounced it is. In any case, such differentiation also means that better-off households may be less exposed to indoor pollution and their consequences.

While more connection points will generally mean more lighting facilities and thus move away from kerosene and better prospects for lessened indoor pollution, the issue of kitchen lighting becomes important as women spend a substantial part of their time in that space. The location of the kitchen within a homestead area thus becomes important.

Poor households may not have any designated covered space as kitchen and cooking may be done in open space. Lighting from the SHS is of little relevance in the context of indoor pollution in such cases. On the other hand, where there is a separate covered space as kitchen, in some cases at least it may be that it is located at a distance from the main rooms. As the normal SHS unit operates well only within a given distance from the charge controller which is usually located within one of the main rooms, kitchens may go without any lighting points from the system. In any case, as the most popular packages usually offer only a few connection points with one usually reserved for TV and another for charging mobile phones, kitchens may often go without lighting from solar electricity. In any case, this illustrates the importance of the number and locations of points of connection for lighting. Hence, the scope for kitchen lighting with the SHS may be somewhat problematic.

The new lighting facility immediately extends productive and working hours in the evening and may have several types of beneficial impacts. Better lighting provides more time to do household chores and/or productive works probably at a somewhat unhurried pace. The facility may also provide more time for reading and study by students as well as pleasure readers. Social interactions as well as sense of security may increase due to lighting. Longer hours during the evening may alter pattern of time use for both men and women, but possibly more for women. Some of these issues need to be investigated keeping in mind the seasonal effects between winter (longer dark period) and summer with shorter nights.

The provision of enough electricity for running a TV may provide scope for entertainment as well as information that may be of value. In fact, the provision of electricity may encourage households to buy TVs that they would have hardly done had there been no electricity. Again, time use pattern will reveal if time for amusements has increased. Another benefit that may accrue is the charging of the mobile phones ubiquitously used even in villages these days. Prior to electrification the owners of mobile phones would have to charge them at specific places and perhaps for a payment causing both financial and physical stress. The commuting frequency and the associated financial stress perhaps would have been less had there been solar electricity in hitherto non-electrified houses. This saves money for charging the mobile phones while earns an income if offered for charging other people’s mobiles.

In view of the above, the research questions pertain to the following:

i. The history of the household in accessing a SHS and its capacity and the proximate causes of such access and its type, the major determining variables being wealth, income, land holding, occupation and education level in the household

ii. The differential use pattern of time and if that varies by men and women in SHS households and also between SHS and non-SHS households, particularly in the evenings

iii. The use of SHSs for various energy services such as lighting, amusements, information gathering on various issues of interest; kitchen lighting

iv. Lighting and study behavior changes

v. Indirect impact of information through radio and TV powered by solar electricity (also see gendered impact below)

vi. Health impact of SHS through lessened indoor pollution or better information through TV/radio

vii. Changes in income and expenditure including those on energy services and energy using devices and their differentials by capacity of SHS, and socio-economic status of households

One may wonder here whether the SHS has any longer term development impact. It may be noted that the SHS that are distributed are not used for direct economic activities because of the rather low capacity of the system as well as due to the reason that the systems are not yet so much used for commercial or similar establishments in a large way. There may be longer term social impacts, but the surge in uptake of the SHS has only been a recent phenomenon. One may have to wait for a few more years for such outcomes to be observed.

1.4.2 Gendered Impact of SHS

Given the particular economic, social and reproductive (biological as well as social) roles expected of women in a typical rural household in Bangladesh, the impact of any intervention that affects the work environment within the household is likely to vary between men and women. Women are an effective force for economic development and they can play an important role in rural electrification as users and providers. At present, opportunities for women in Bangladesh as energy service providers are, however, extremely limited, and therefore the potential remains unfulfilled. Yet rural women are a natural choice for such services as they represent the largest group of rural energy users, particularly of biomass fuel for daily cooking.

As users of energy services from SHS, women may be profoundly impacted as their timing of household chores may change due to availability of better lighting, study periods of female students may change while cooking itself may also be done late in the evening (if the kitchen has light points from SHS which needs to be investigated as pointed out earlier) rather than everything being done hurriedly in semi-darkness which may affect nutritional quality of the food that is prepared.

The research questions in terms of gender analysis of SHS in Bangladesh may be (i) whether socioeconomic status of rural women could be enhanced by increasing their opportunity and participation in alternative energy service delivery or not; and (ii) if the SHS brings positive impacts in terms of social indicators, what additional efforts can supplement it to bring radical changes in shifting gender roles and responsibilities?

The following direct and indirect social impacts are expected from wide dissemination of SHS:

(i) training for women in operation of SHS thereby imparting them certain technical knowledge which may instill a sense of empowerment;

(ii) as indicated earlier, replacing kerosene lamps and *kupis*, and thereby creating healthier environments for the women and their families; may be more effective if kitchens are lighted with solar electricity;

(iii) possible positive impact on food safety, as women may be able to cook after dark with better lighting;

(iv) as indicated earlier, shift in time use due to better lighting allowing them (particularly female students) more time for study at night, do household chores such as sewing which have been done hurriedly before;

(v) more leisure time as well as opportunity to get involved in income generating activities by women;

(vii) access to information (through television, radio) which might help in raising awareness on health, education, rights etc.

(viii) longer waking hours at night may also lead to changes in reproductive behavior particularly if information on reproductive health and behavior is available through TV.

1.4.3 Issues Related to Program Delivery and the Role of the POs

As mentioned earlier, the SHS are delivered through the POs: 4 of them account for most of the SHSs installed so far (see Chapter 2). POs procure the system components (panels, batteries, charge controllers etc) and install the systems at the households. The households buy the systems under a micro-credit arrangement with the POs. At the time of installations, households pay a down payment of 10-15 percent of the system price and the rest is repaid over a 3 year micro-credit period. After installations, POs apply for refinancing (for part of the micro-credit part extended to households) and a capital buy-down grant to IDCOL. The following explains the financing mechanism:

a) The capital buy-down grant (a fixed $20 per system[5]) is provided to help POs reduce the cost of SHS at the household level. POs also receive a grant of US$3 for 'Institutional Development';

b) In addition to the capital buy-down and institutional development grant, POs also receive refinancing of the micro-credit part from the IDCOL (80 percent of the micro-credit extended to customers) at a flat rate of interest of 6 percent for a period of 6-8 years;

c) Against such direct incentives to POs, households receive the SHSs on credit for 3 years at a flat rate of 12 percent. POs thus receive benefits from the interest spread and the repayment period spread.

d) There is also a provision of buy back of batteries and their replacement when their life is over.

The objectives for such incentives are to encourage the POs to pass on the subsidy as much as possible onto the clients so that the rural households receive SHS at a cheaper price and that a robust and regulated market chain is established at the rural level that ensures a) quality of products, b) environmental safety requirements, c) availability of facilities for repair and maintenance and d) supply of spares, bulbs, etc. at the local level.

As part of the business of selling SHS, POs train local people for repair and maintenance and establish market chains for smooth supplies of spares, and products related to SHS maintenance. POs have also established a system through which households can buy SHS at discounted prices if they opt for shorter repayment period. Households also have the option to buy SHS for cash (in which case POs are entitled to get only the capital buy-down grants from IDCOL and not the institutional development grant). There is, within an apparently regulated marketing system, thus scope for flexibilities making effective prices vary by POs and also by the nature of demand from the clients. Against such a backdrop, it is therefore, important to examine and analyze:

a) the extent of trickle down of grant benefits up to the household level, or in other words the differential costs borne by the clients,

[5] When the IDCOL program first started in 2003, the capital buy-down grant was $90 per system. Over time, as has been explained later, the subsidy has been gradually reduced to the current level of $20/SHS (during the survey period, subsidy was $25 per system). From January 2013 however, this subsidy is applicable for only smaller systems. IDCOL has also recently allowed several new POs to the program. For these new POs, the capital buy-down grant allowed is $25 per system for all sized SHS installed by them in addition to $3 per system institutional development grant. This is to allow meeting the up-front costs of setting up establishments of the new POs.

b) the distribution of such benefits by categories of households (poor and non-poor households),

c) the sustainability of the SHS market in absence of the intervention through IDCOL,

d) the extent of satisfaction at the household level in terms of quality of service and products,

e) whether there are any differences in terms of realized benefits among POs, and

f) how far the POs have taken measures to reduce environmental impact from disposal of lights, the batteries and charge controllers.

Further, whether accrued benefits to household vary because of PO characteristics such as size of its operation or concentration in an area are also important hypotheses to be tested in the study.

As has been explained earlier, the program has seen a gradual reduction of subsidy from the initial \$90 per system to \$20 per system by Dec 2012. Such declining rates of grants, everything else remaining the same, will of course raise the cost per unit of operation. Yet, it is expected that these declining rates of grants given to POs will induce the management to change its operating systems to cut down costs and ultimately provide enough incentives to sell more SHSs which may not be subsidized through grants.

It was commented on an earlier version (and also one of the peer reviewers) that the grant does not vary with size of the POs. The table shows the gradual reduction in subsidy to the whole program, i.e. the first 20,000 SHS installed (by all 5 POs operating at that time) got a subsidy of \$90. Over time, as more and more SHS were installed, the subsidy was gradually reduced to the current rate of \$20 per system.

Again, as one of the peer reviewers commented, this is only for the 650,000 SHS. I suggest deleting this to avoid mis-understanding of the readers (as the consultants have mis-understood it).

It is also possible that several POs operating in one area might encourage competition and benefit SHS buyers through lower prices for the units as already indicated earlier.

POs will also differ because of their staff quality and consequently the potential backstopping services provided to clients and finally on the performance of the installed SHS and thus on their impacts. Then again POs may experience differences in the demand by clients for specific packages as well as their own offers. Because subsidies were fixed for all systems (until Dec 2012 after which subsidies are available only for smaller systems except for those installed by new POs), smaller lower-cost systems benefited more from the subsidy as the fixed subsidy is a higher percentage of the systems costs of the smaller sized SHS than the bigger sized systems. Because of this incentive, POs may prefer to push for lower Wp packages, the impact may differ as the total facilities enjoyed by a client with higher Wp package will be different from one with a lower Wp package. One would, thus, expect at least higher levels of impact for higher Wp packages.

What all these mean is that the PO characteristics, its costs of operation, staffing quality and supervision capacity all become important and should, therefore, be issues on which information may be collected and analyzed with respect to impact of the SHS.

1.4.4 Technical Installation Quality, Backstopping and Operations of the SHS

IDCOL has been pivotal in promoting SHS in rural Bangladesh through POs. It has maintained that SHS supplied by them are standardized through a technical committee and so despite the absence of any formal regulatory body, IDCOL's approach has ensured better quality units compared to other market-based suppliers. One would thus expect a standardized technical quality of installation. While laboratory verification of this claim is beyond the scope of the present exercise, the availability of other contemporaneous reports may help us in understanding this issue.

The SHS is composed of several inter-locking components. Unless these are well-configured to work with the other components, the system may not provide the optimum service and its life may also be shortened lowering the overall benefits to clients. It has been noted in the literature that in many cases the technical quality may not be of the desirable standard. One may note the following quote from Chowdhury et al. (2011).

> "Qualitative and quantitative assessments of the obtained data revealed various technical and organizational shortcomings, mostly during implementation at the grassroots level. With regard to the design of the installed SHSs notable factors were the over/under-sizing of system components and underperformance of the components with respect to the approved guideline and specifications. Placement of the key components such as solar panels and flooded-cell batteries were sub-optimal and in some cases posed health and safety risks to the end users. At the top end of the organizational tree, the approved specifications and guidelines needed more frequent updates to keep up with the advances in technology and to incorporate research findings from Bangladesh and elsewhere. At the bottom end of the organizational tree, there is a need for further technical training of the field operatives. For effective maintenance and operation of the SHSs, the field offices need to be equipped with appropriate on-site and off-site testing facilities to enable them to make informed decisions.

No significant evidence of underperformance of the system components due to ageing was found. It should be noted that the project was only six years old. However, the quality of the components in recent installations worsened from the initial installations. The size of the market, combined with recent growth patterns, makes it imperative that the supply chain is more robustly regulated to protect end users' rights and investments."

IDCOL had been notified of these findings and it is reported to have given stern warnings to the POs for their low quality of installation and post-installation services. Given all these, there are two types of monitoring issues. First, how is IDCOL monitoring the technical and management quality of installations and their running by the POs? Second, one needs to have a technical evaluation of the installed systems, the technical monitoring capability of the POs, and the quality of their technical backstopping services. All these should form an integral part of the evaluation of the SHS and its impact. Specifically, the following may be noted based on experience:

- The SHS is composed of several inter locking components. Unless these are well configured to work with the other components, it may not provide optimum service.
- Many technical and organizational shortcomings are faced during the implementation at the client and the field level of the POs.
- At the bottom end of the organization tree, there is a need for further technical training of the field operatives. For effective maintenance and the operation of the SHS, the field offices need good equipment and testing facilities.
- The quality of the components in recent installation has worsened from the initial installations.
- The problem of battery disposal may become an important issue in future as this is known to have become a major source of pollution in China and India.[6]

This study therefore tries to assess the technical quality of installations and operation based on information from POs both at the head quarters and branch level as well as those from the household. This will be one of the set of factors that may influence the performance of the SHS and thus ultimately on the impact and benefits of the SHS.

1.4.5 The Characteristics of the Present Market

The present and the future market for SHS is based on the idea that the areas where the rural electrification has not reached out or is not expected to reach within the foreseeable

[6] See Gottesfeld and Cherry (2011)

future is the total potential market for the SHSs in the rural areas. However, for realizing the potential size of the market one has to consider various issues related to finance, subsidy, costs to clients and POs, quality of service and the like. While there has been a sizeable expansion of the market for the SHS what exactly are the characteristics of this market and how do the POs appraise them for their business operations have not been properly documented so far.

Subject to the performance of the SHS based on the various criteria that have been discussed above, further potentials of the systems need to be known with some kind of certainty. A market survey to assess the future potentials needs to take into account not simply the theoretical limits, but also practical intervening factors such as growth in income of households, the need for higher levels of energy that may be demanded over time and also the expansion of the rural grid electrification system in the country. Once done, such an assessment will guide to the investment needs and associated supplementary activities.

For this, the first question to be answered is the present potential demand. For this one needs to know the future potential off-grid areas and its extent in terms of households that may be served. For this, one may need information on the expansion plan of the Rural Electrification Board (REB), which is the agency responsible for extending grid electricity in the rural areas. The total number of such rural households adjusted for those in the existing and future REB areas (say for 5 years) gives the potential size of the market for SHS in the medium term. Not all of this market is expected to be targeted, however, because of various supply and demand constraints. Particularly, it may be that POs think that the present SHS market in the designated off-grid areas is saturated and they thus look for their business beyond such designated areas. This has obvious implications for the size of the market and scope for business.

On the demand side, one needs to know from the household survey the factors that affect demand in an area. Ideas about the future values of such factors such as income growth and prices of energy alternatives such as kerosene will be able to guide about the total demand over time. This needs to be matched with supply from POs.

As indicated earlier, POs operate under various imperatives and constraints. These need to be analyzed in detail based on the interviews/communications with the POs where specific market demand related information and information on their plans for expansion need to be sought. Particularly cost-minimizing efforts by the POs need to be probed.

Successful deployment of SHS is dependent among others on the policies of the government regarding energy prices, and financing and refinancing policies for renewable energy in general and SHS in particular. These issues need to be analyzed critically. Such information may provide insights about the market imperfections (if any) and ideas regarding innovative special support measures that might minimize the market imperfections and moreover might redress social and economic imbalances. The market study, therefore, may indicate how a significant and sustainable contribution to rural electrification can be achieved with a large-scale dissemination of SHS, building on existing markets or creating responsive market structures supported by appropriate financial services.

1.4.6 Size of the Market and Future of Expansion

Given that a substantial expansion has taken place in installing SHS, that subsidy is being gradually reduced, that reaching systems in new areas has costs, and that not all potential clients turn out to be final customers for various reasons, the pertinent question arises is what proportion of this potential will be realized upon which the POs can base their future expansion plan. In doing that one needs to consider the levels of subsidy expected to be available. Indeed, it appears that because of the uncertain quality of the on-grid rural electrification service, there is demand from the POs to allow them to do business in the on-grid areas and provide SHS as a back-up system for those who can pay the unsubsidized cost. This demand will be more persistent if the present off-grid market is thought to be saturated or is expected to be so soon. The contingent valuation method is used to determine the size of the market in future at least within the off-grid areas.

1.4.7 Carbon Emission Reduction due to SHS

There is another issue which perhaps did not enter the initial conceptualization behind the SHS program. This relates to the issue of low carbon development. The Conference of Parties (COP) under the United Nations Framework Convention on Climate Change (UNFCCC or simply, Convention) at its 13th meeting (COP 13) in Bali in 2007 decided that every country either on a mandatory basis or voluntarily will have to do its part in lowering global emission of green house gases (GHG). Bangladesh, as an LDC, is exempt by the rules of the Convention from any mitigation (i.e., GHG lowering) activity. However, after the Bali COP, Bangladesh, in its submission on Bali Action Plan, has committed to keep its GHG emission as low as possible given that adequate financial and technological help are available. Later, during the Durban Conference of Parties in 2011, decisions have been made towards mitigation actions (i.e., emission reduction measures) by all countries by 2020. The encouragement of the SHS program fits Bangladesh's earlier commitments and later international developments well as it avoids the use of fossil fuels for generation of electricity.

The avoided emission of carbon is a benefit to the global community and can be sold in the global market and indeed, the IDCOL has entered into an agreement with the World

Bank on this type of sale. There are two types of caveat here, though. *First*, one school of thought argues that the avoided carbon needs to be compared on a life cycle basis, not simply the direct avoidance of release of carbon due to the SHS (Fthenakis and Kim, 2011). Second, given that the pattern of energy consumption may change, the totality of the emission may change. It is difficult to speculate at this moment, however, as to which direction it may go. But the direct avoided emission may be estimated under this study as a first step towards understanding the potentials of SHS in the process based on the information on the consumption of energy collected at the household level.

Given the issues that need to be discussed and analyzed as described above the rest of the report is structured in the following manner: Chapter 2 provides a history of the SHS along with some of its present characteristics including the financial mechanisms and subsidy issues and outline approach to assess the impacts on the outcomes with an elaboration of the sampling methodology and survey administration. Chapter 3 presents some of the background information on adopters and non-adopters. Chapter 4 analyzes the operations of the SHS in the households including why households buy an SHS as well as the capacity they buy and also indicates some of the apparent effects. Chapter 5 verifies the findings of the previous chapter through exploiting more rigorous impact assessment methodology for some of the critical impacts. Chapter 6 then goes on to analyze some of the issues of ground level operation using information mainly from the field offices of the POs. Chapter 7 sheds light on the households' willingness to pay for the SHS and the potential impact of withdrawal of subsidy by IDCOL, the changes in the financing mechanisms and its parameters (rates of interest charged to POs and households, time of repayment etc.) on crucial variables such as the rate of return to POs and interest rate to be charged to households. The chapter also simulates the potential market size for the SHS. Chapter 8 examines the technical problems the households as well as the POs encounter and their management with regard to different components of the SHS. Chapter 9 provides a few concluding remarks.

CHAPTER 2

SOLAR HOME SYSTEMS IN BANGLADESH

2.1 The Present State of Installation of SHS

By December 2012, more than 1.7 million SHSs have been put in place by 30 POs selected by the IDCOL which in turn is supported by World Bank, German Development Cooperation (GIZ), Kreditanstalt für Wiederaufbau (KfW), EU, ADB, IDB and a multi-donor trust fund, GPOBA. Even though the REB also has its own SHS program, the numbers are comparatively few. Besides, unlike the IDCOL system, SHS installed under the REB are owned by itself, the users only pay power tariff at designated rates. IDCOL's SHS program is run through POs. These are essentially NGOs or their business wings. The IDCOL selects the POs based on certain criteria and the POs identify the households and enterprises or other organizations for installing the SHS.

The information up to 31 December 2011 indicates that just one PO, the Grameen Shakti, accounted for 58 percent of the SHS that have been installed (Fig. 2.1). Three more POs viz. RSF, BRAC, and Srizony Bangladesh had installed respectively 15, 6 and 4 percent of the SHS. By divisions, the percentage distribution was Dhaka: 26, Chittagong: 19, Barisal: 19, Khulna: 11, Rajshahi: 14 and Sylhet: 11. Even though, one may find a skewed distribution by POs, distribution by division is not that uneven but given that Dhaka and Chittagong are the divisions served most by REB, one would have expected the distribution to be more in favor of underserved ones, viz., Barisal, Khulna, and Rajshahi. For that matter, activities of one PO, Srizony Bangladesh is concentrated more or less in the Southwest region which includes the Barisal and Khulna divisions.

2.2 The Basic Delivery System

2.2.1 Choice of POs and IDCOL's Role

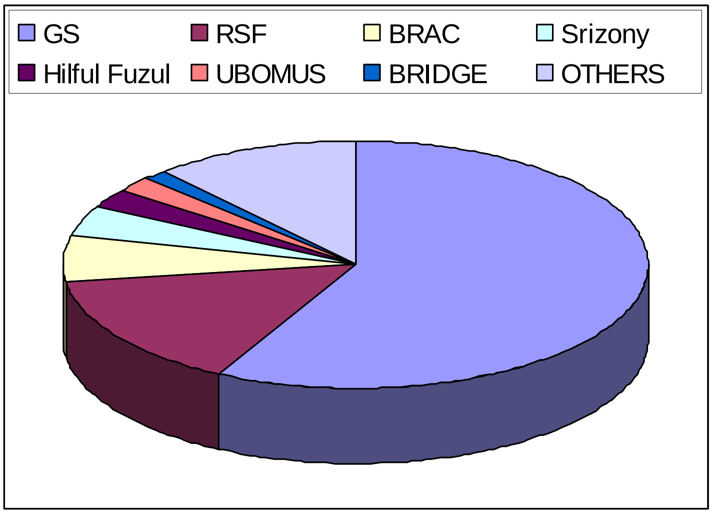
The procedure of selection of POs by IDCOL follow certain general rules which means that whether a PO will be chosen depends on its institutional capacity assessment based on various indicators related to accounting and audit management, staffing, years of operation, assets position, experience of operation in off-grid area and credit operations experience and related other criterion. Even if the POs pass these tests, although the area they choose is also part of this exercise, it is still PO's own choice to operate in any particular off-grid area. In most cases there are other POs operating in a particular area. We sense that this competition may have led the POs to compromise with their service quality (see sub-section in Chapter 6).

2.2 Financing SHS by Households and POs

The financial viability of SHS program is a major issue in its implementation. How far clients self select themselves into the program depends among others on the price of the particular package that is on offer, credit program for financing the purchase as well as the cost of the alternative, which in this case is kerosene that is also subsidized (Chakrabarty and Islam, 2011 and Komatsu, Kaneko and Ghosh, 2011).

Figure 2. 1: Distribution of Solar Home Systems Installed by POs

(as of December 2011)



On the financing mode for SHS under IDCOL sponsorship, there is a down payment that has to be made and also payment in installments which also carry interest. As Table 2.1 shows, a 50 Wp system may cost a household a total of nearly US$ 400, a hefty sum in rural Bangladesh. In any case, that means, while kerosene is replaced by electricity and thus may change the energy use pattern to an extent, given that the budget constraint of the household is changed may have even greater change in the consumption of energy and may be also on other items. It will be found out later in the report how energy consumption may have changed.

Table 2. 1: Financing of a 50Wp SHS to a Household

Credit Sale

SHS cost	USD 380
System buy-down Grant A:EU 30	USD 38.40
Remaining Cost	**USD 341.6**
Household Down payment (15%)	USD 51.24
Credit to customer (Tk)	**USD 290.36**
IDCOL refinance (80%)	USD 232.29
PO Contribution (20% of loan amount)	USD 58.07
Institutional Development Grant B : EU 8	USD 10.24

Financing terms of loans from PO to household	
Loan (Tk)	USD 290.36
Loan duration	3 years
Total Interest charge (12% p.a. flat)	USD 104.53
Total household payment	USD 394.89
Monthly household installment	**USD 10.97**

Source: IDCOL

2.3 Field Surveys: Households, Community and PO Branches

Three surveys were conducted for the collection of primary level information. There was the main survey of households split into three sub-groups, SHS adopters (treatment) in SHS villages, SHS non-adopters (Non-adopter 1 in SHS villages) and SHS non-adopters (Non-adopter 2) in control or non-SHS villages. The selected districts, upazilas and treated /control villages are shown in Table 2.2. The details of the sampling framework, the spatial sampling design, the choice of the various sub-groups of households and its rationale are discussed at length in Annex to this chapter.

Table 2. 2: Selected Districts, Upazilas, and Treated Villages

Division	District	Upazila	Sample Villages	
			Treated	Control
Barisal	Barguna	Amtali	Sonakhali, Tariakata	C1, C2
		Barguna Sadar	Kumrakhali, Sharishamuri	C1, C2
	Barisal	Barisal Sadar	Nalchap, Rajar Char	C1, C2
		Muladi	Alimabad, Charbatamara	C1, C2
	Bhola	Bhola Sadar	Kandokpur, West Char Pata	C1, C2
		Char Fashion	Aminpur, Hazariganj	C1, C2
	Patuakhali	Dashmina	Ali Pura, Bara Gopaldi	C1, C2
		Galachipa	East Neta, Kazi Kanda	C1, C2
Chittagong	Chittagong	Banshkhali	Gandamara, Premashia	C1, C2
		Sandwip	Maitbhanga, Rahmatpur	C1, C2
	Noakhali	Hatiya	Dashpara, Sukh Char	C1, C2
		Noakhali Sadar	Kazir Char, West Maiz Chara	C1, C2
Dhaka	Mymensingh	Dhobaura	Bakpara, Baligaon	C1, C2
		Haluaghat	Kumarghati, Songra	C1, C2
	Netrokona	Kendua	Jalli, Shivpur	C1, C2
		Kaliajuri	Adampur, Chandpur	C1, C2
	Shariatpur	Bhederganj	Baher Char, Char Bhaga	C1, C2
		Shariatpur Sadar	Kachikata, West Atpara	C1, C2
Khulna	Bagerhat	Chitalmari	Aruaborni, Barashia,	C1, C2
		Mongla	Joykha, Nitakhali	C1, C2
	Khulna	Dumuria	Chitramari, Khorerabad	C1, C2
		Terakhada	Adampur, Kushala	C1, C2
	Satkhira	Shymnagar	Gumantoli, Kamalkati	C1, C2
		Tala	Khanpur, Magura	C1, C2
Rajshahi	Bogra	Sherpur	Khanpur, Simla	C1, C2
		Shivganj	Chakpara, Chandrapukur	C1, C2
Rangpur	Kurigram	Chilmari	Duttar Char, Mudafat Kalikapur	C1, C2
		Rajibpur	Baliamari, Kodalkati	C1, C2
Sylhet	Sunamganj	Dharmapasha	Kandapara, Rupnagar	C1, C2
		Jagannathpur	Chilaura, Paragaon	C1, C2
	Hobiganj	Chunarughat	Parkul, Bholarjum	C1, C2
		Lakhai	Begunai, Faridpur	C1, C2
7	**16**	**32**	**64**	**64**

Note: For each row C1 and C2 stand for control village 1 and 2 against the treated villages listed. Selection process of the C1 and C2 are elucidated in the relevant text.

A community survey was conducted in each village to elicit information on village characteristics in order to find out if these might influence acquisition of SHS. It may be noted that no census was carried out as the data base of the IDCOL already identifies the SHS households, which also by method of residual identifies the non-SHS households too.

One or more PO branches provides the supply, installation and after sales service to clients in the treatment villages. In 64 such villages, 167 branches of the POs operating in the villages were collected to assess the performances of the POs. This means that a village has been served in most cases by more than one PO or its branch. Of the 167 branches, just about 60% were of 4 POs, namely the Grameen Shakti (44 branches), the Rural Services Foundation (30 branches), Srizony Bangladesh (18 branches) and BRAC Foundation (8 branches).

2.4 Some Pertinent Findings from the Community Survey

Are the SHS and control villages similar or quite different from each other? If they are broadly similar, then one can with some confidence, apply various methods to find out the impact of the intervention, as characteristics of the locality which is external to the household is not likely to confound the results. The treated and control villages are compared in this chapter in terms of their physical, infrastructure and socio-economic situation. These are the issues that may bias the results of comparison between SHS and non-SHS households unless controlled for.

As explained above a community survey was carried out in each village where households were interviewed. That means information was obtained from 64 treated (SHS) and 64 control (non-SHS) villages. It was turned out that the control villages also had a few SHS installed in some of the households. But they are so few that for all practical purposes, these are control villages. Similarly not all of the households in the treated villages adopted the SHS. This caveat should be borne in mind while interpreting the results.

2.4.1 Physiographic Condition

Nearly one-half of the SHS villages are situated in normal plain land, the other half being in char lands and areas prone to river erosion. The corresponding proportions for control villages are 66% and 34% respectively. Apparently therefore, at least in half of the areas where SHS have reached, grid is not expected to be reached in the foreseeable future. Also there is an apparent mismatch between treated and control villages. However, the relevant chi-square statistics is not significant at all meaning that the physiographic situations in treatment and control villages are not that systematically different.

2.4.2 Landownership Pattern

Next we tried to find out the land ownership patterns in the villages. These are shown in Table 2.3. While percent of household belonging to landless and marginal landholding groups are higher in the control villages vis-à-vis the treated ones, it is evident that there is hardly any difference in the aggregate patterns.

Table 2.3: Landholding Patterns in Sample Villages

(% of households)

Village type	Landless (<0.5 a)	Marginal (0.5<1.0 ac)	Small (1.0<2.5 ac)	Medium (2.5-<5.0 ac)	Large (7.5 & + ac)
SHS	43	23	18	11	2
Control	52	28	11	5	1

2.4.3 Education, Health, Financial and Transport Infrastructures

Table 2.4 shows the incidence of educational and healthcare facilities in the sample villages. Apparently, the SHS villages are better endowed with educational facilities within the village. On the other hand, the SHS and control villages are at par with regard to healthcare facilities within the village.

Table 2.4: Percent of Villages having Education, Health and Other Facility

Indicator	SHS	Control	Significance level in difference in provisions
Primary school	92.2	67.2	High
High school	43.8	29.7	Weak
College	12.5	1.6	High
Madrasa	57.8	34.8	High
Community clinic	43.8	23.4	High
NGO run clinic	14.1	9.4	NS
Union health center	17.2	12.5	NS
Immunization center	79.7	71.9	NS
Any health service center	85.9	78.1	NS
Bank within 1 km	12.5	9.4	NS

***Note*: High: significant at 1% or less; Weak: significant at 10%; NS: not significant**

One may argue that so long as a facility is within easy reach, it does not necessarily have to be within the village. If we take 1 km as the most school children including girls may have to walk to school, then it has been found that both SHS and control villages are at par in having access to the most basic educational institution, i.e., a primary school. Considering this and the situation related to healthcare facilities, SHS and control villages do not differ widely in access to social infrastructure such as schools and healthcare clinics.

Besides social and financial infrastructure, we tried to find out how well connected the villages are to the transport network (of any kind - rail, road or waterways) of the country. Unsurprisingly, the results indicate that both the treated and control villages are somewhat off the transport network and residents need to travel more than 5 km in case of half the SHS villages. The corresponding proportion for control villages is just about a third. The differences are not statistically significant and thus the two types of villages may be taken to be at par with each other in the context of connectivity to the transport network.

2.4.4 Water and Sanitation Facility

Access to safe drinking water is essential for a healthy life. We have tried to find out how the sample villages fare in this regard. Drinking water sources have been categorized as unsafe (open source, arsenic contaminated and others not specified) and safe (any kind of tube well without contamination, piped water and ring well). The results indicate that 95% of the villages, both SHS and control, rely mainly on safe water sources. On the other hand when the sanitation situation is considered it has been found that in case of SHS villages, the predominant places of defecating are more or less sanitary in nearly 80% of the villages. The corresponding percentage in case of control villages is 75%. Thus, both types of villages have similar water and sanitation situations.

2.4.5 Incidence of Safety Net and Other Programs

There are several safety net programs in the country. Roughly half of the villages in either category appear to have quite a few of them. Apart from such programs there are various others run by NGOs. These mainly include income-generating activities in agriculture and small business, education and micro-credit in both types of villages. The relative importance of the incidence of the activities is quite similar across the type of village.

2.4.6 Disaster

Various disasters occurred in the sample villages during the last five and last one year. These included mainly flood, drought and river erosion. Roughly up to about 60% of the villages faced these hazards and similarly across the type of villages.

On the whole therefore we find except for one or two indicators of village characteristics SHS and control villages do not differ much from one another. Of course, this applies in aggregate. Any particular village from either of the groups may deviate from the general pattern. Despite this, we can conclude that the differences in impact of SHS on the households are not much likely to be influenced by these village characteristics.

Annex to Chapter 2

A 2.1 Sampling framework for Households

Insofar as the households are the main users of SHS, the sample size may be estimated through an approach based on confidence level and precision rate. For this purpose, the following formula may be used:

$$n_h = [(z^2)*(1-r)*f*k]/[r*p*s*e^2] \quad (2.1)$$

where, n_h is the sample size in terms of number of households to be selected; z is the normal density function that defines the level of confidence desired; r is an estimate of an indicator to be measured by the survey; f is the sample design effect; k is a multiplier to account for the anticipated rate of non-response; p is the proportion of the total population accounted for by the target population; s is the average household size; and e is the relative margin of error.

In this study, the level of significance was set at 10 percent with the consequent z-value of 1.64. Insofar as the penetration of the SHS is less than 5 percent, the indicator r is set at 0.04. The design effect denoted by f was set at 2. The extent of non-response was set at 5 percent. It may be recalled that the proportion of rural population as per the latest census was about 75 percent; thus 0.75 was used for p. The size of 4.53 of rural household as found in the latest HIES was used for s. The extent of relative margin of error was set at 10 percent. Given the values of the parameters the above formula results in a total sample of SHS households at 3,990. Thus, the actual sample size was determined at 4,000.

To facilitate the comparison between the SHS households (treated) and those without SHS (controls), a decision has been made to split the data. Of these 4,000 households, data on 1,600 households were collected from villages where adoption of SHS was relatively high. Data on 2000 households were collected from the adjacent union parishads[7] where SHS installation is sparse in order to minimize the spillover effects and the unobserved heterogeneity vis-à-vis the treated households. Data on the rest 400 households were collected from *the same villages where data on treated households were collected*.

It may be noted that intervention outcomes of 1,600 treated households were matched with the ones of the 2,000 households from adjacent villages. Thus, this set of control households were used for impact assessment. In contrast, data on 400 control households from the treated villages were used to assess the determinants of participation in the program. In other words, this set of control households were used to assess the proximate factors that deter them in the adoption of the technology.

[7] A Union Parishad is the lowest administrative unit of local government in Bangladesh.

A 2.2 Spatial Sampling Design

To ensure geographic and PO representation, a multistage stratified cluster sampling method was adopted to select households considering them as the ultimate sampling units and upazilas as primary sampling units. The sampling frame was based on the data provided by the IDCOL on the cumulative installations of SHS up to December, 2011. In the first stage, 16 districts were selected from seven administrative divisions based on the highest concentration (installation) of the SHSs in the districts. However, this selection criterion left two regions under-represented or missing: Rajshahi region does not have a district in the 16 top districts and Sylhet region has only one district in the top 16 districts (Sunamganj). To circumvent this practical problem, two districts from the top 16 list (Chandpur and Tangail) were replaced by Bogra (Rajshahi region) and Hobiganj (Sylhet region).[8] It may be noted that there is high variation across the districts: while concentration appears to be the highest in Sunamganj (over 68,000 SHSs), it appears to be the lowest in Bogra (about 21,000 SHSs). Around 58 percent of the total installed SHSs are concentrated in these sixteen districts.

In the second stage, two upazilas from each of the selected districts were selected at random based on the concentration of the installed SHS; thus a total of 32 upazilas were selected. Similarly, two villages were selected at random from each upazila: a total of 64 villages from 32 upazilas. While the selection of upazila is proportionate to the size of installations, two special criteria were imposed in addition: (i) programs should be in the villages for at least 3 years and (ii) village should have at least 50 SHS households for ease of sampling. When these criteria were invoked, a few of the 32 upazila were always found to have only one village even after repeated random draws. Several attempts were made and the best case scenario leaves 2 upazilas (one in Barisal and the other in Kurigram) with one village. These two upazilas were revisited and the selection criteria were relaxed: from each of these upazilas, the village with highest concentration of SHSs (which was less than 50) was selected to make up for the shortage of villages. From each of the other upazilas, two villages were selected randomly. Table 2.3 in Chapter 2 shows the selected districts, upazilas, and villages across the seven administrative regions.

A2. 3 Selection of Households

Stratified random sampling method was applied to select households from the selected villages. The basis for stratification is size of SHSs (10Wp, 20Wp, 40Wp, 80Wp, 130Wp, and 150Wp) that are installed in the village under financial and technical support

[8] Although Bogra and Hobiganj do not belong to the top 16, these districts are within top 24 with reasonably high concentration.

from IDCOL. To ensure representation of different size of the panels, 25 households were proportionally allocated among size groups using the following formula:

$$n_h = \frac{n}{N} N_h \qquad (2.2)$$

where, n_h is the number of households with h^{th} size of the SHS, n is the total number of SHS households HS to be selected from a village, N is the total number of SHS households of all size and age, and N_h is the total number of SHS households belonging to the h^{th} size group. It may be noted that data on 25 SHS households will be collected from each of the treated villages.

Special attention was give to collected data on those control households that match with the treated households based on some observable characteristics. For collection of data on 2,000 control households, the lists of cumulative installation of the SHSs in each of the villages of the respective upazila were collected from each of the POs operating in it. The level of SHS concentration by village was assessed by collating the lists from all such POs. The two villages with least concentration were selected as control villages for the two treated villages in the same upazila.[9] Data on 31/32 households were collected from each of the two villages. Since the control villages are also located in the same upazila but have fewer installations of SHS, one may surmise that there would be sizable overlap between them and the treated villages in terms of observable characteristics making them ideal control villages. Besides controlling for the village level characteristics, treated households were matched with non-treated households based on household level observable characteristics.

For collection of data on 400 control households that live in the treated village, special instruction was given to the enumerators. In essence, data on 6/7 households who have not adopted the SHS technology were collected from each of the 64 treated villages. Particular attention was given in choice of these household so that they match with the 25 SHS households who have already been interviewed based on observed socioeconomic characteristics.

It may be noted that more controls than treated households (2000 vis-à-vis 1600) were selected to increase the number matches through the PSM and hence to increase the robustness of the estimates. The whole survey was completed during May-June 2012. A total of 24 field officers and field supervisors were deployed for data collection under the supervision of a survey coordinator.

[9] Note that two treated villages were selected in each of the selected upazilas.

CHAPTER 3

BACKGROUND CHARACTERISTICS OF SAMPLE HOUSEHOLDS

3.1 Preamble

Each household in SHS villages have the option to install a unit under certain conditions by the POs. Not all do. Similarly in villages where there are only a few or no SHS sold by POs, practically none may have a SHS installation. The pertinent question is: is there any systematic difference between the three groups, viz., SHS households in treated villages (adopters), non-users of the SHS in the same villages (non-adopter 1) and those without SHS in control villages (non-adopter 2). As will be seen later it is the comparatively economically well-off households who appear to adopt SHS more than others. Then again education, particularly, women's education has a distinctive positive role.

In this chapter we particularly try to find out if adopters and non-adopters differ systematically on certain characteristics of the households. We do not infer any causality here, however. Some of the traits may have been instrumental in adoption of SHS while some others may be partly a result of SHS adoption. These causalities will be investigated in later chapters.

3.2 Incidence of SHS Adoptions

Table 3.1 shows the unweighted adoption rate by administrative divisions and at the national level. These indicate that the adoption rate is the highest in Chittagong (90%) division and the lowest in Khulna (19%). The unweighted average indicates that at most a third of households in the treated villages (where diffusions of SHS have taken place) have actually adopted the technology. Table 3.1 also shows the weighted adoption rate.[10]

Table 3.1: Percentage of SHS Adopters by Division

Division	Adoption rate (unweighted)	Adoption rate (weighted)
Barisal	25	48
Chittagong	90	24
Dhaka	31	21
Khulna	19	21
Rangpur		13
Rajshahi	22	11
Sylhet	34	34
All	34	23

Note: For the unweighted column, Rangpur is subsumed within Rajshahi Division

[10] The weighting procedure is explained in the Annex to this chapter.

3.3 Adoption Pattern by Sex of Household Head

Most households surveyed are male-headed. This is also true in general for adopter as well as non-adopter households in the SHS village. Yet, one observes somewhat higher proportion of female-headed households among the users compared to non-users of SHS (Table 3.2). One also finds that while the pattern by sex is statistically significant at 10%, when only the pattern within SHS villages are considered the pattern is significant at 5%. However, the same pattern is not observed in all divisions. It is in Chittagong division that one finds the strongest such pattern in that 21% of all heads of adopter households in SHS villages are women.

Table 3.2: Adoption Pattern for SHS by Gender of Household Head

Sex	Adopters	Non-adopters 1	Non-adopters 2	All
Male	1475 (92.2) [40]	381 (95.2) [10]	1864 (93.2) [50]	3720 (93.0)
Female	125 (7.8) [45]	19 (4.8) [7]	136 (6.8) [49]	280 (7.0)
All	1600	400	2000	4000

Note: Non-adopters1 refers to SHS non-users in SHS villages while non-adopters 2 refer to non-users in control villages.
Figures in parentheses are percentages of column totals and those in brackets are percentages of row totals.

3.4 Adoption Pattern by Age of Household Heads

Age of household head does not appear to have any discernible influence on adoption of SHS as among all types of adopters and non-adopters, slightly more than 50% of household heads are in the age-group of 30-50 years followed by about a third in the age-group of 50 years and above. Broadly a similar pattern is observed in all the divisions. However, when household heads are categorized by sex, one finds that among female-headed households, those with younger heads appear to have adopted SHS comparatively more. Thus, among such adopter households those headed by women in the age group of below 30 years constitute 21% of all adopter female-headed households. The comparative figure for adopter male-headed households is 13% or so.

3.5 Adoption Pattern by Education of Household Heads

Education levels of heads of households by adoption category show a clear pattern. As Table 3.3 indicates, the proportions of illiterates and primary incomplete education are much less observed among the adopters. The relative incidence of higher level of education, is much higher among the adopters than the non-adopters whether in the SHS villages or in the control ones. More than 40% of adopters household head studied in secondary level or beyond while the proportions for non-adopters is only half of that. All these patterns are statistically highly significant. A similar situation obtains in the divisions in general.

Table 3.3: Education Levels of Household Heads

Education level	Adopter	Non-adopter 1	Non-adopter 2	All
Illiterate	433(27.1)	166(41.5)	936(46.8)	1535(38.4)
Primary incomplete	190(11.9)	68(17.0)	298(14.9)	556(13.9)
Primary complete	276(17.3)	74(18.5)	334(16.7)	684(17.1)
Secondary incomplete	410(25.6)	63(15.8)	296(14.8)	769(19.2)
Secondary complete	157(9.8)	15(3.7)	74(3.7)	246(6.2)
Secondary+	134(8.4)	14(3.5)	62(3.1)	210(5.2)
All	1600	400	2000	4000

Note: See Table 3.2.
Statistical significance test: $\chi 2 = 265$, df = 10, sig 1%.

3.6 Role of Women's Education among Households

While we examine the issue of education, it comes as a striking phenomenon that women's education may have a significant role. What we have tried to find out if the households have at least one primary completed woman or a secondary level completed woman in the family. Our hypothesis was that the presence of such women would have positive impact on adoption of SHS to facilitate education of children. Indeed, this is what we have found.

Around 70% of SHS households have at least one woman in the family who has passed the primary level compared to around 60% for other groups. For secondary education, 20% of adopter households have at least one woman having passed the secondary level compared to 10-12% in the non-adopter categories. Later during other related analyses we will again see how women's education relates to various aspects of SHS adoption and impact.

3.7 Adoption and Occupation of Household Heads

The households are engaged in myriads of occupation. For analytical purpose, these can however be categorized in 4 broad groups, viz., self employment in farming, non-agricultural, wage workers of any category and others. The patterns of adopters and non-adopters clearly indicate that while non-adopters have similar occupational patterns in both treated and control villages in that self-farming and labor predominate among them, adopters differ somewhat from that pattern. Among the adopters, non-agricultural occupations of household heads appear to be much more prevalent than either self-farming or worker category. The pattern is also statistically significant (Table 3.4). It may further be noted that the patterns are similar across divisions with high level of significance (not shown).

Table 3.4: Occupations of Household Heads

Occupation	Adopter	Non-adopter 1	Non-adopter 2	All
Self-farming	541(33.8)	153(38.2)	759(38.0)	1453(36.3)
Non-agricultural	733(45.8)	131(32.8)	605(30.2)	1469(36.7)
Labor	128(8.0)	74(18.5)	442(22.1)	644(16.1)
Others	198(12.4)	42(10.5)	194(9.7)	434(10.8)
All	1600	400	2000	4000

Note: See Table 3.2.
Statistical significance test: $\chi2 = 182$, df = 6, sig 1%.

3.8 Adoption and Total and Agricultural Land Holding of Households

The land holding size of adopters is in general larger than those of non-adopters whether in the treatment or the control villages. The difference is more in case of control villages. The differences are clear when the adopters and non-adopters are compared by land holding category and by the average size of land holding (Table 3.5). The same is the case with agricultural land holding (Table 3.6). In all cases the differences are highly statistically significant.

As the land holding size differs substantially across adopters and non-adopters, it comes as no surprise that the aggregate value of land of adopters will be higher than either of groups of non-adopters. The average values per household (including other agricultural assets) have been found to be Tk. 1.09 million, Tk. 0.72 million and Tk. 0.65 million for adopters, non-adopter 1 and non-adopter 2 categories respectively (see Table 3.7).[11]

Table 3.5: Landholding Categories among Households

Landholding (in decimals)	Adopter	Non-adopter 1	Non-adopter 2	All
Landless	5(0.3)	1(0.2)	20(1.0)	26(0.7)
1-250	1159(72.4)	346(86.5)	1790(89.5)	3295(82.4)
251-500	236(14.8)	36(9.0)	139(7.0)	411(10.3)
501-750	91(5.7)	9(2.2)	34(1.7)	134(3.4)
750+	109(6.8)	8(2.0)	16(0.8)	133(3.3)
All	1600	400	2000	4000
Average	244.7	134.5	105.1	163.9

Note: See Table 3.2.
The aggregate landholding size is unweighted. The average holding of adopters is statistically highly significantly different from average holdings of both groups of non-adopters

[11] The estimated average excludes 14 cases of outliers (higher than Tk. 10 million) mostly in case of adopters group. Including the outliers raise the values for adopters but keep others broadly unchanged thus further accentuating the adopter-non-adopter differences.

Table 3.6: Agricultural Landholding Categories among Households

Agricultural Landholding (in decimals)	**Adopter**	**Non-adopter 1**	**Non-adopter 2**	**All**
Landless	393(24.6)	121(30.2)	737(36.8)	1251(31.3)
1-250	847(52.9)	240(60.0)	1115(55.8)	2202(55.0)
251-500	217(13.6)	31(7.8)	121(6.0)	369(9.2)
501-750	60(3.8)	2(0.5)	17(0.8)	79(2.0)
750+	83(5.2)	6(1.5)	10(0.5)	99(2.5)
All	1600	400	2000	4000
Average	208.6	107.4	82.0	135.2

Note: See Table 3.2.
The aggregate landholding size is unweighted. The average holding of adopters is statistically highly significantly different from average holdings of both groups of non-adopters.

3.9 Adoption, Household Size and Number of Students

Larger households are likely to have more children and the demand for lighting for their study may induce these households to adopt SHS more, if available. On the face of it, however, it appears that household size has little role in deciding about adoption. The patterns of distribution of household size across adoption category show little difference from one another. However, when the data are disaggregated by division, except in Rajshahi and Barisal, one finds weak to strong positive relationship between adoption and size of household. Thus, there may be some support to the hypothesis.

To see if the numbers of students in the family differ between adopters and non-adopters, the mean numbers of students were estimated for each group. Apparently there was no discernible difference as the average for adopter households, it was 1.59 while for non-adopters, it was more or less 1.43 for both the non-adopter groups. But the differences are systematic and statistically significant between the adopter and both the groups of non-adopter households.

3.10 Asset Holding among Households

We have earlier indicated the average value of land and agricultural asset holding by adopter and non-adopter households. However, despite being probably the most important, there are other non-land and non-agricultural assets that need to be taken into consideration. In whatever form it is held, total asset of a household allows it to take risky decisions. On the other hand as acquisition of SHS may entail some costs (such as travel to the PO field office) although much of the investment costs are on credit, own financial capability allows one to be comfortable with such arrangements. One can of course argue that the present asset holding including financial ones may be a result of business opportunities, if there are any, yet, it might be instructive to have some idea of differences of such holding by adopters and non-adopters.

With these caveats in mind, Table 3.7 shows that adopter households have higher asset levels, be it total or land (including agricultural machineries) or financial and the differences are all statistically highly significant indicating that the differences are systematic, not arising at random.

Table 3.7: Asset Holding among Households

(in TK. '000)

Asset Type	Adopter	Non-adopter 1	Non-adopter 2
All	1361.2	875.9	778.7
Land+	1092.4	717.8	649.9
Financial	106.4	43.8	40.2

Note: Land includes value of agricultural machineries. Financial capital includes cash as well as financial instruments which can be readily converted into cash. Excludes outliers such as those having TK. 10 million or more (14 out of 4000 cases). All differences between adopter households and any of the non-adopter group is statistically significant.

3.11 Income among Households

We have investigated how total annual income, agricultural income and non-agricultural income are different among adopters and non-adopters. For this we have used only a subset of information on households which have shown non-negative income. The total sample size is thus somewhat reduced to 3929. The average income figures are shown in Table 3.8.

Table 3.8: Average Annual Income Levels among Households

(in Tk. '000)

Income Category	Adopter	Non-adopter 1	Non-adopter 2
Total	160.0[a,b]	90.4[a]	89.1[b]
Agricultural	64.3[a,b]	45.9[a]	42.8[b]
Non-agricultural	58.5[a,b]	28.9[a]	30.7[b]

Note: Strictly speaking, only agricultural income (mainly crop-based) is net of costs of inputs and expenditures; other income is basically receipts and may not be net of inputs expenditure. The total income thus may be somewhat overstated.
Figures having the same suffix are statistically different at 1% level of significance

3.12 Borrowing and Debt among Households

The information on loans and outstanding debt situation indicate that again it is the adopter households of SHS who have the largest average loan (during the last one year) as well as the highest debt compared to both the groups of non-adopters (Table 3.9). As we have seen earlier the adopter households are economically far better than other two groups and thus may be more credit-worthy which may be one of the reasons for their higher amount of loan and outstanding debt.

Table 3.9: Average Annual Borrowing and Outstanding Debt among Households

(in Tk. '000)

Indicator	Adopter	Non-adopter 1	Non-adopter 2
Borrowing	54.6	31.7	25.9
Outstanding Debt	45.7	27.9	22.9

3.13 Food Consumption, Expenditure and Security among Households

Rice is the staple and main item of food providing calories. Taking rice consumption as the indicator of access to food, we find that across the groups of households, there is hardly any difference in per capita consumption of rice (of whatever variety), around 3.2 kg/person/week. But this may hide the actual situation as consumption information was obtained for one week during the survey and also at a time when the main rice crop, boro, has been harvested indicating a general over-all availability in the country. This may or may not reflect the over-all situation. We have therefore asked the respondents regarding their self-assessment of household food security in terms of access to food. And here we find interesting differences.

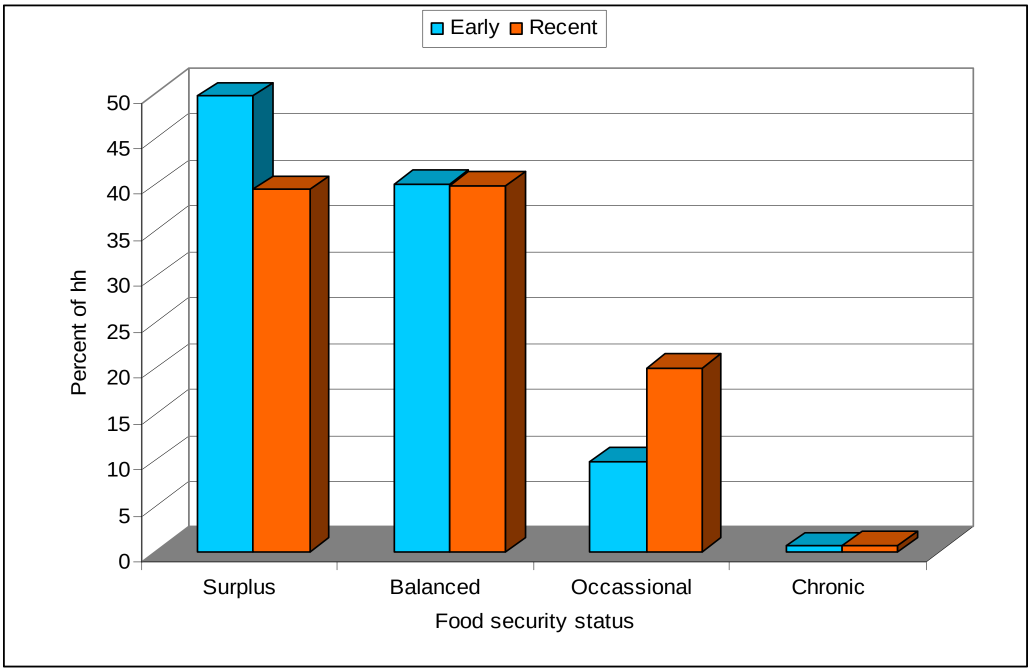
Against the background of better economic conditions of the adopter households, it is not surprising to find that while more than 40% of such households have surplus food for consumption, even nearly one-fifth of these households suffer from occasional hunger due to food deficit. The corresponding proportions in the non-adopter 1 and non-adopter 2 groups are nearly 30 and more than 20% (Table 3.10). Food security is thus better in adopter households despite apparently similar average consumption of rice. In fact, if food security is a reflection of better economic condition, early adopters are found to be better food secure, at least at present, than the late adopters (Fig. 3.1).

Table 3.10: Self-assessed Food Security Situation among Households

(in % of column total)

Deficit indicator	Adopter	Non-adopter 1	Non-adopter 2
Surplus	41.4	23.2	21.6
Balanced	40.1	49.2	49.8
Occasional	17.9	27.2	28.1
Perennial	0.7	0.2	0.6

Fig. 3.1: Food Security Status by Time of Adoption



3.14 Expenditures for Asset and Skill Acquisition of the Households

Earlier we have indicated that financial or near cash asset holding by households are different in different types of households with adopters having an edge over non-adopters When we look at actual asset acquisition over the preceding year, we find that it is again generally higher for adopter households. But the differences are even more striking for skill acquisition through educational expenses as shown in Table 3.11. Adopter households on average spent almost 50-80% more for children's education than the non-adopter households.

Table 3.11: Average Per Capita Annual Expenses for Asset Acquisition and Education

(in Tk.)

Indicator	**Adopter**	**Non-adopter 1**	**Non-adopter 2**
Asset acquisition	7519	7106	4781
Education	7576	5173	4392

3.15 Early vis-à-vis Recent Adopter Characteristics

Adopters are likely to be a mixed bag of households. Yet we find that some of the characteristics that differentiate an adopter from a non-adopter appear to be true also between early and recent adopters. Recent here means installations since 2009 while early means before 2009. Roughly this provides for a cut-off point of installations at least 3 years old and those which are less than 3 years old. Such categorization shows that early adopters are likely to be somewhat aged, having better education, higher income and land holding, less likely to be female-headed, women comparatively better educated and kitchens having SHS connections (Table 3.12). All these are statistically significant patterns. Thus what is generally true for adopters hold more for early adopters compared to the recent ones.

Table 3.12: Differentials in Characteristics of Early and Recent Adopters

Characteristics	Early adopters	Recent adopters
Age of household head (years)	48.8	44.8
HH head's education (primary and above) percent	79.3	56.1
Female headed household (percent)	4.9	8.7
Women's education (at least primary)	87.3	73.0
Total land holding (decimal)	434	192
Total income (in Tk. '000)	200.8	131.4

Annex to Chapter 3

Weighting Procedure for Adoption Rates for SHS by Division

Since the unweighted average adoption rate may be misleading due to population and sample mismatch, the weighted average adoption rate across the seven administrative divisions needed to be calculated. The weights for users and non-users were calculated in several steps.

Step 1: The total numbers of users of the SHS by divisions were enumerated from the administrative data base of the IDCOL to get a surrogate population of users.

Step 2: The total numbers of rural population by divisions were enumerated from the latest Census of Population and the total numbers of users of the SHS were subtracted to get the surrogate population on non-users.

Step 3: The weight for users in a division was calculated as the ratio of the population of users found in Step 1 to the total sample of users interviewed in the survey. Similarly, the weight for non-users in a division was calculated as the ratio of the population of non-users found in Step 2 to the total sample of non-users interviewed in the survey.

It may be noted that the weight variable for non-users calculated this way is not 100% accurate as the surrogate population variable derived in Step 2 also includes grid households in rural areas. Number of grid households in a division should be subtracted from the surrogate population estimate found in Step 2 to get a more accurate value of the estimate. That said, in absence of that information the estimated weight variable for non-users is a reasonably good approximation.

CHAPTER 4

SOLAR HOME SYSTEMS IN HOUSEHOLDS: ACQUISITION AND APPARENT EFFECTS

4.1 Acquisition of SHS

The analyses based on bivariate tables (cross-tabulations or comparison of means) in Chapter 3 indicate which variables may influence the adoption of the SHS. These, however, do not indicate their independent influence on the decision to adopt. To test if these have such independent influence we have estimated a simple logistic function using categorical variables. For this purpose, we have recoded continuous variables (such as age or income) into categorical variables. Such categories help us understand if the odds-ratios are compared to the reference categories which are also indicated in the estimates reported in Table 4.1. Note that the regression estimates are based on only the adopters and non-adopters in the treatment villages because it is only in these villages that the non-adopters had the choice to adopt or not. In the control village no such choice exists. It should be noted here that there are two more such estimates using the probit model, a very similar econometric method. But, the one equation estimated for subsequent PSM exercise (in Chapter 5) is different in that it takes into account the situation in the control villages while the other one (in Chapter 7) is estimated based on contingent valuation. Yet it would be instructive to see that the results here and in the PSM-related probit estimates provide similar implications except that the latter uses village characteristics which the logistic regression here has not. It has taken the village characteristics as the same for SHS and non-SHS households being drawn from the same villages and thus using only household characteristics for sharper focus related to policy.

The variables chosen as independent factors are defined as follows: (i) annual household income Tk. 50,000 or less = 0, Tk. between 50001 and 100000 = 1 and Tk. 100000 and above = 2 (ii) male headed household = 0 and female headed household = 1, (iii) age of household head 20 years or less = 0, 21-30 years = 1, 31-50 years = 2, and 50 years or more = 3, (iv) household head’s education less than primary = 0, and primary passed and above = 1, (v) household having no female with primary passed education = 0, and with at least one primary passed female = 1, (vi) household head’s occupation others = 0, and non-agriculture = 1. In each case, the first category is the reference category. The odds-ratios thus indicate the odds in favor of acquisition of SHS as one moves from the reference to other categories.

Given the above explanations we now move to the estimates (Table 4.1).[12] These indicate that except for age of household head, all other variables exert significant and substantial independent influence on the decision to adopt. Take for example, the case of income. We have earlier found that the adopters have higher income than non-adopters in the same villages. Here we find that it is indeed the case that as one moves up the income ladder, particularly the highest one, the probability to adopt SHS is more than double compared to the lowest income group. Similarly female headed households are 83% more likely than male-headed ones, everything else remaining the same, to acquire an SHS, if offered by POs. Then again households with at least one primary passed woman are 39% more likely to adopt SHS compared to those who do not have such women in household. These results are somewhat similar to the ones shown later in Chapter 5.

Table 4.1: Logistic Regression Explaining Acquisition of SHS

(SHS = 1; Non-SHS=0)

Independent variables	**Coefficient**	**Sig. level**	**Odds-ratio**
Annual HH Income up to Tk. 50,000	Ref		
Annual HH Income between Tk. 50,000 and 100,000	.186	.211	1.204
Annual HH Income Tk. 100,000 and above	.795	.000	2.214
HH head is male	Ref		
HH head is female	.605	.022	1.831
Age of HH head up to 20 years	Ref		
Age of HH head between 20 and 30 years	-.125	.852	.882
Age of HH head between 30 and 50 years	-.138	.833	.871
Age of HH head 50 years and above	-.136	.836	.873
HH head's education less than primary	Ref		
HH head's education at least primary	.569	.000	1.767
HH head's occupation others	Ref		
HH head's occupation non-agriculture	.444	.000	1.559
No primary educated woman in the HH	Ref		
Primary educated woman in the HH	.327	.011	1.386
Constant	.409	.537	1.505
-2 log likelihood	1879.70		

4.2 The SHS Capacity

The SHSs are differentiated among others by their capacity to produce electricity and is calibrated in terms of Wp. POs offer various capacities of SHSs. These range from 20 Wp to 135 Wp and all types of capacities in between. These are offered on credit and also on cash terms basis. The cash terms constituted less than 2% of all SHS sold since the POs had begun their operations in the sample areas. On the other hand, except certain capacities (20, 40/45, 50/55, 60/65, 70/75 and 80/85 Wps), others are rather infrequent accounting for just above 2% of all SHS sold. We therefore examine the frequently observed SHS capacity

[12] Note that some of these variables may be highly correlated such as for education and income. However, multicollinearity usually leads to insignificance of the variables. If despite such multicollinearity, variables have statistically significant coefficients that means the relationship is particularly and systematically strong.

and those given on credit. The time pattern of these sales as reported by the PO field offices in the SHS areas are shown in Table 4.2.

Only three categories of capacity predominate, 20, 40/45 and 50/55 Wps. Among these the 50/55 Wp appeared to be most dominant historically followed by the other two categories. Over the last one year, however, it appears that the 20 Wp category is making inroads at the expense of others, particularly the 50/55 category which still remains a major category, though.

Table 4.2: Distribution of SHS by Capacity Sold on Credit

(in percent)

Wp	Total	Last 12 months	Last 1 month
20	23.9	33.4	40
40/45	21.2	22.4	21.2
50/55	30.9	24	21.3
60/65	13	10.5	8.9
70/75	2	1.7	1.5
80/85	9	8	7.1
Number	91122	28973	2927

Source: BIDS Survey of PO Field Offices

4.3 Other Pertinent Background Information on the SHS in the Households

A few of the pertinent information on the SHSs in operation are provided in Table 4.3 for understanding their efficacy in impacting on the various indicators of household well-being and welfare.

Table 4.3: Some Pertinent Information on Sample SHS

Indicators	Information	Comment
POs from which bought	GS: 70%; BRAC: 6%; RSF: 7%; Srizony 3.7%; Others: 13.6%	
Mode of purchase	99% on credit	
Price	From 12489 (20 Wp) to 40911 (85 Wp)	
Loan duration	3 Years: 91% of cases	
Interest mode	Flat rate: 86% of cases	
Delayed payment of installments	436 (27%) cases	116: Once; 112: twice; 208: 3 or more times
Capacity	20 Wp: 18%; 40 Wp: 21%; 50 Wp: 34%; 65 Wp: 12.4%; 85 Wp: 6.1%	
Vintage	78% less than 3 years; 22% more than 3 years	
Lighting points	2-5 points: 93%	2 points: 23%; 3 points: 27%; 4 points: 31%; 5 points: 12%
Kitchen lighting	40% of households	20 Wp: 15%; 40 Wp: 36%; 50 Wp: 41%; 65 Wp: 64%; 85 Wp: 71%
Operating instructions provided	56% yes; 44% no	
After sale service agreement	92%	82% given service upon call; 75% within 1-2 days of call

The above table clearly indicates the following:

ix. Most SHS have been purchased on credit from Grameen Shakti while 3 or 4 other POs are also somewhat important but they are far behind;

x. Only a few packages of SHS predominate as also pointed out earlier. The 50 Wp is the median choice (of one-third of customers), but newer ones are likely to be more in 20 Wp category;

xi. Most SHS are of comparatively recent vintage as 78% have been purchased only over the last 3 years and many since 2 years or less;

xii. Costs vary by package, but higher package ones may be slightly cheaper on a unit Wp basis;

xiii. While the interest is at a flat rate and the loans are for 3 years mainly, some 27% has delayed on payment of installments, among them roughly one half for 3 installments or more;

xiv. Number of lighting points of course varies by capacity and mostly the use is for 2-5 lighting points varying monotonically as the capacity increases with 2 points for 20 Wp and 6 for 85 Wp. Further, most interestingly, 40% of SHS households have lighting in the kitchen and that tendency is positively related to the capacity one uses.

xv. While proper instructions have been provided on the operation of the SHS to one or more of household members, the proportion claimed to have so received was rather poor at 56%.

xvi. After sales service agreements exist in most cases and service provided mostly within 1-2 days of call.

4.4 Who Purchases What Package of SHS?

4.4.1 Role of Economic Factors

Earlier in Chapter 3 we have indicated that the SHS households are economically more or less better off than the control households. However, as the choice of SHS package may depend on various other factors including the same set of economic factors particularly due to price differentials of the SHS of various packages, we intend to find out if installation of a particular package of SHS has a positive relationship with household's economic well-being.

Four indicators have been used to find out the relationship. These are total land holding, agricultural land holding, total value of assets (including financial assets) and total household income per year. The mean values of these values by main types of SHS system are shown in Table 4.4. The indicators clearly show that the demand for and use of higher package of SHS is positively related to all of them. The pattern gets stronger beyond the low SHS package, namely 20 and 40 Wp.

4.4.2 Role of Socio-demographic Factors

An attempt was made to find out which of the socio-demographic factors such as age of household head, education, women's education, occupational categories of household head etc have any systematic relationship with the package of the SHS purchased by the household. There was no monotonic pattern in most of the cases. In certain cases the relationship appears to be more of an inverted U-shape with the apex being at the 50 Wp package which is understandable given the overall importance of this package of SHS.

Table 4.4: Economic Indicators by SHS Capacity

SHS Package (Wp)	Total land (decimal)	Agricultural land (decimal)	Asset value (Tk. '000)	Total income/year (Tk. '000)
20	121	100	800	104
40	176	142	1262	106
50	263	222	1682	160
65	401	355	1726	205
75	223	176	1966	167
85	477	440	3273	218

4.4.3 An Integrated View

What capacity of SHS people buy thus apparently depends on many factors. These need to be considered together. While our data indicate that the pattern may not be much systematic and the explanatory power of the variables together is not much, we still provide an integrated view of the economic and socio-demographic factors and their role in determining size of SHS to acquire.

Before we show the estimated equation, it may be reiterated that the capacity of the SHS is denominated in watt-peaks is also a discrete variable. For discrete dependent variable, the Ordinary Least Square (OLS) is not a preferred estimation method. A Poisson regression is often used in such cases. We have used a Poisson regression equation although it may also have some strong assumptions.[13] We reproduce below the estimated Poisson equation:

Wp = 2.73 + 0.0658 ln income + 0.068 eddum – 0.067 Occdum + 0.074 Wed +

[13] Kennedy, P., A Guide to Econometrics, 4th Ed, Blackwell Publishers,, Malden, Mass., USA,1998, pp. 236-37.

(0.003) (0.008) (0.008) (0.009)

0.135 ln age - 0.026 POdum – 0.132 Instaldum;

(0.013) (0,008) (0.009)

Pseudo R sq = 0.069;

Figures in parentheses are standard errors – all coefficients are significant at 1% or lower.

Log-likelihood = -9027.37 ; chi-sq highly significant

where

Wp is capacity of SHS in watt-peak;

Income is household's annual income in BDT;

Eddum is dummy for household head's education taking value 1 for at least primary passed; 0 otherwise

Occdum is household head's occupation dummy with non-ag -1; 0 otherwise

Wed is a dummy for family having at least one primary passed female– 1 for yes, 0 for none

Age is household head' age;

POdum dummy for Grameen Shakti – 1; 0 otherwise

Instaldum is dummy for year of installation – 0 for before 2009;

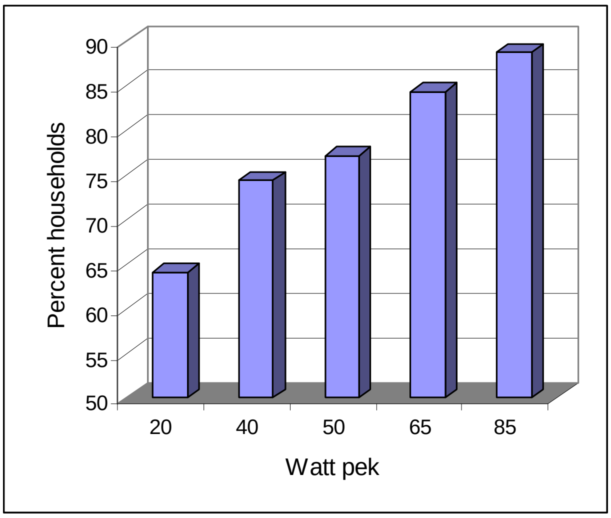
1 for since 2009

The equation shows that all have statistically highly significant coefficients. Note that the alternative OLS model returned more or less the same relationships except for PO dummy which was not significant. This indicates that PO characteristics may have some influence on what capacity the clients choose to buy. Note that the manner in which the PO dummy has been constructed means that clients of Grameen Shakti choose the lower capacity systems compared to those of others. In fact this may have to do with the fact that the Grameen Shakti has the largest market share and as over time the tendency is to choose lower capacity systems, this reflects by and large the situation of Grameen Shakti sales. The choice of a single equation estimation method means that at least one more methodological problem may remain.

The Wp equation is contingent upon the adoption equation and thus the Wp equation should be based upon a Heckman correction term. This may perhaps make the explanatory power better. While we have not done this, on the other hand, it has been established that the socio-demographic and economic factors associated with the household are probably the main determinant behind choice of the size of SHS.

We would like to pick up the women's education issue again because of its ubiquitous nature of influence. The Figure 4.1 shows how the proportion of households rises with women's education status (of at least primary passed) in family as the SHS size increases. This is really astounding.

Fig. 4.1: SHS Capacity in Households with at Least One Female Member with Primary Education



4.5 Energy Consumption in SHS and Non-SHS Households

The sample households irrespective of the SHS status are dependent on kerosene and biomass for their energy requirement. About 80% of the households use fuel wood or non-fuel wood biomass for cooking and related activities. While 62% of the SHS households reported to use kerosene, the incidence is significantly higher at 99% among the non-SHS households. In contrast, other sources of energy vary between 53% among the SHS households to 64% among the non-SHS households. Although a large share of households uses the other sources, energy consumption from these other sources is very low.

Table 4.5: Household Access to Various Energy Sources by SHS Status (%)

Energy Source	SHS	Non-SHS		
		Non-adopter 1	Non-adopter 2	All non-adopters
Fuel wood	86.5	82.2	79.8	80.2
Non-fuel wood biomass†	78.1	80.0	84.4	83.7
Kerosene	61.6	97.0	99.1	98.7
SHS	100.0	0	0	0
Other sources‡	52.5	65.0	63. 8	64.0

†Non-fuel wood biomass sources are dung, tree leaves, crop residue, charcoal, jute stick, and briquette.

‡Other sources include LPG, candle, dry cell batteries, storage batteries, generators.

Insofar as the analysis based on the above percentage may be misleading, the actual kgOE/month of the households was compared between SHS households and those without SHS. The results presented in Table 4.6 show that the overall consumption of energy differs little between the adopters and non-adopters. On the other hand, SHS households consume about 64 kgOE/month of energy from fuel wood vis-à-vis 51 kgOE/month for households without the SHS. Similarly, SHS households consume 62 kgOE/month of energy from non-fuel wood biomass vis-à-vis 65 kgOE/month for households without the SHS. These empirical findings with regard to consumption of biomass energy are not important per se as the ownership of SHS does not substitute these types of energy consumption. The same conclusion applies to energy consumption from other sources. However, it may be noted that ownership of the SHS replaces consumption of fossil fuel , particularly kerosene among the SHS households. The average level of consumption per month in non-SHS households is almost 3.5 times the average level in SHS households The difference in the level of consumption is statistically significant as shown in Table 4.6 and also later in the next sub-section. In any case, as the overall consumption of energy does not differ significantly, one can surmise that the use of SHS changes the composition of energy consumption.

Table 4.6: Energy Consumption from Various Sources (kgOE/month)

Energy source	SHS	Non-SHS			t-statistics
		Non-adopter 1	HHs from non-SHS villages (N=2,000)	All non-SHS HHs (N=2,400)	
Fuel wood	63.57	55.68	49.61	50.64	4.48**
Non-fuel wood biomass†	61.87	61.20	65.48	64.80	-1.27
Kerosene	0.76	2.39	2.33	2.34	-23.62**
SHS	3.56 (3.56)	0	0	0	
Other Sources‡	0.29	0.02	0.02	0.02	5.36**
All sources	104.32	97.05	97.21	97.18	1.30

†Non-fuel wood biomass sources are dung, tree leaves, crop residue, coal, jute stick, and briquette.

**Figures are statistically significant at a level of 5% or less.

Note: Figures are average values for households that actually use particular energy sources, that is, households with zero consumption are excluded from the calculation. The figure in parentheses is energy consumption from SHS in kWh/month as the latter is a more common unit than former for electricity.

4.6 The Substitution of Kerosene

One of the main uses of the SHS is for lighting. As shown earlier depending on the capacity of the SHS, households do have 2-5 lighting points (also see next sub-section). The more of these, the lower is the use of kerosene for lighting which is its main use in the rural areas, although there are theoretically other possibilities of its use such as for cooking which is a costly alternative to use of biomass and hence hardly seen in any rural household. Question therefore arises whether this replacement of kerosene by solar electricity really takes place and if it does, by how much.

There are different ways of testing this hypothesis. If any such reduction takes place upon adoption of SHS, over how long a period and whether among the adopter households, kerosene use is reduced as the capacity and hence lighting points increase. As we shall see below, the former hypothesis is proved clearly but the second one is supported rather weakly at best. To test this hypothesis we have regressed kerosene use per month (KerQ) by a household on several of its characteristics. These are as follows: (i) **Adcat** is Adopter category taking 1 for adopters; 0 otherwise; (ii) **ln income** is the household's total annual income in Bangladesh taka; (iii) **ln HHHage** is the household head's age in years; (iv) **ln hsize** is the size of the household in number; (v) **HHHed is** a dummy variable with primary passed household head equals 1 and 0 otherwise; (vi) **HHHocc** is an occupational dummy for the household head with non-agriculture equals 1; and 0 otherwise..The dependent variable is log of kerosene use per month in liters (ln KQ).

The estimated equation is

$$\ln KerQ = \underset{(71.8)}{0.34 - 1.32\, Adcat} + \underset{(8.37)}{0.057 \ln income} + \underset{(4.38)}{0.126 \ln HHHage} + \underset{(12.39)}{0.296\, Hsize}$$

$$+ \underset{(2.03)}{0.034\, HHHed} + \underset{(2.83)}{0.049\, HHHocc}\ ;$$

Adjusted R-square = 0.619

Note: Figures in parentheses are t-statistic. All coefficients are significant at 1% except education of household head which is significant at 5%.

The equation is self-explanatory. It shows that all the explanatory variables have statistically significant coefficients and that when a household uses SHS, its consumption of kerosene falls. How much it falls may be found by calculating exp (coefficient of Adcat) which is 3.67. This means an average adopter uses 3.67 liters of kerosene less per month compared to an average non-adopter of SHS when other factors influencing kerosene use are held constant. For the current clientele size of 2 million SHS at the present this comes to more than 88 million liters of kerosene. We will later see the carbon reduction implications of this lower consumption.

Does size of SHS matter in deciding how much kerosene is consumed? Hardly, as for 20-55 Wp range the average per month varies little with a range from 0.60 to 0.67 liters. Only for the 60-65 Wp range does it fall substantially to 0.54 liters but the fall is not statistically significant. We also tested if the length of SHS installation lowers kerosene consumption. It does not as whether the installation has been put in place before 2009 or afterwards makes practically no difference (0.60-0.61 liters). This seems counterintuitive. But perhaps an explanation may be found in the equation estimated above. For example, let us look at the coefficient for log income.

Kerosene consumption with respect to income has an elasticity of 0.06 i.e., for every 10% rise in income the kerosene consumption rises by more than half a percent. For other variables the elasticities are higher; for household size it is 0.3. All these mean that as other variables change along with adoption, and remember that in most case adoption is positively related to these variables, these have a positive impact on kerosene consumption, negating much of the negative effects of the SHS adoption. This results in an apparent static level of consumption among the adopters in whichever way they are categorized.

One should at this stage, point out that while the average kerosene consumption in SHS households falls very substantially, it is not altogether eliminated, possibly because of three types of reason. First, the transition from non-adopter to adopter does not mean that the kerosene using appliances are immediately discarded and as many SHS households have adopted the panels only for a few years, their kerosene using appliances have remained. In any case, the number of lighting points may not cover the entire house and thus, kupis and hurricanes are still needed for those rooms (in many cases, the kitchen) without solar light. Third, when a new technology is adopted, people may often keep the old one as a kind of back-up if the new one does not function smoothly (and there are some problems identified with the SHS particularly in recent installations, see Chapters 6 and 8).

The monthly expenses at present for control households are around Tk. 325. For the SHS households, it is the sum of several components. The first is the cost of whatever little kerosene is used for lighting (74% of 0.61 liters) plus present value of the loan repayments made for first 3 years after which a charge controller needs replacement plus any operation and maintenance costs (changing of batteries and charge controllers plus minor repairs for next 17 years, considering that the life of a solar panel is 20 years) and then dividing the whole amount by 240 months (= 20 years x 12).

For illustration, we simplify it by taking the case for 20 Wp, its price of Tk. 12,560 (inclusive of down payment) which at the stipulated rate of 12% interest rate results in an annuity of Tk. 417 (over 36 months of repayment period). The total payment made comes to about Tk. 15,000. Assuming a 10% operation and maintenance costs, and the replacement of the batteries, charge controllers, and lights after their useful lives, the monthly annuity comes to about Tk. 41.72 for 20 years (the estimated useful life of the solar panels). Total levelized cost for SHS acquisition and operation and maintenance comes to Tk. 104 per month. Adding Tk. 30 per month for kerosene purchased for lighting (assuming that this level of kerosene lighting is maintained), the total monthly payment comes to about Tk. 135. Clearly even at current prices and not considering opportunity costs (and thus not applying PV method for loan repayments over time), SHSs spend at most Tk. 135 per month on a levelized basis. It is just about 41% of control households' costs of lighting per month on a levelized basis. Thus, given the quality of lighting and the levelized costs at current prices, solar lighting is clearly a superior option.

4.7 SHS and Appliance Use

Even though the POs offer SHS of different Wp levels, the preferences, as shown earlier, of the households are limited to 20, 40, 50, and 65 sizes. The most popular choice, historically, appears to be 50 Wp size. As expected, there is a positive correlation between the size of the package and the number of lights that it supports; while only 2 light bulbs are used in a 20 Wp size as many as 6 light bulbs are used in an 85 Wp size of SHS as indicated earlier. Among the most popular systems, the use of SHS for charging lanterns ranges between 9 and 24 percent. However, about half of the households use electricity from the system to run a black and white TV.

Table 4.7: Appliance Use Pattern by SHS Households by Selected SHS Wps (%)

(N=1,505)

SHS capacity (Wp)	Share among SHS users (%)	Tube lights (number)	Charger lights/lanterns	TV
20	18.0	2.1	8.9	5.4
40	22.3	2.9	9.3	33.4
50	36.9	3.7	12.9	46.3
65	13.5	4.4	23.7	50.4
75	2.3	5.6	29.1	44.2
85	7.0	5.9	14.2	50.7
All capacities	100.0	3.6	13.3	36.9

Note: Findings exclude certain SHS capacities that are less common such as 21 Wp, 30 Wp, 63 Wp, 83 Wp, etc. They constitute 5.8% of all SHS users.

4.8 The Carbon Emission Issue

For the lack of a more suitable place to put it, we would like to discuss briefly the issue of reduction in carbon emission due to installation of SHS. SHSs replace the use of kerosene to an extent because of its reduced consumption for lighting. We have seen that on the average, an SHS household consumes 3.67 liters less of kerosene per month compared to non-SHS households which comes to, given 2 million SHS in the country, 88.06 million liters less per year. Given that a liter of kerosene has a calorific value of 38 MJ/liter and that a terra joule of calorie from kerosene releases 19.6 MT of carbon and also that carbon dioxide molecules are 44/12 times heavier compared to carbon, the total emission reduction due to the SHS at present comes to just over 240 thousand MT of carbon dioxide. However this is only the direct reduction in emission. If the same electricity was to be supplied from grid, this means that SHSs are actually helping reduce more than the above estimate as solar power is also indirectly replacing a minimum of certain level of natural gas (which is the main primary fuel for generation of electricity).

4.9 Some Apparent Impact of SHS

In this sub-section we are reporting on results of analysis between adopters and non-adopters what might be the differences on some interesting impact variables. Here we do not control for the other variables which may also have an impact on these SHS-based impact variables. Hence we would like to call them as apparent or indicative impact of SHS. We need to still distinguish what might be the impact of SHS independent of the other confounding variables. This is attempted in Chapter 5 where influences of other variables have been controlled as far as possible.

4.9.1 Children's Education

Solar lights discharge higher levels of lumens compared to kerosene lamps and hence the former are brighter. The brighter lights allow children to study longer hours and hence may enhance their chances of better grades and completion of higher levels of educations. While the first outcome can be verified immediately, the second and the third may take a longer period to manifest. Table 4.8 shows such comparisons. It may be noted that children with solar light amenity study longer in the evening than those without it. Both the boys and girls on an average study 10-12 minutes longer with solar lights than those without it. The differences are statistically significant. As expected, availability of solar lights at home does not contribute to higher level of attendance at school. Even though the year of schooling completed was found to be higher for children with SHS than those without it and the differences are significant for both boys and girls, it should not be attributed to the adoption of the system as the average length of using the SHS by household was less than 3 years in many cases.

Table 4.8: Educational Outcomes by SHS Adoption for Children of Aged 5-18 Years

Education outcome	SHS HHs	Non-SHS HHs			t-statistics***
		HHs from SHS villages	HHs from non-SHS villages	All non-SHS HHs	
Evening study duration (minutes/day)					
Boys	131.3	118.5	120.3	120.0	2.68**
Girls	127.3	115.6	114.9	115.0	2.99**
School attendance (%)					
Boys	77.5	75.9	72.6	73.2	1.30
Girls	81.2	80.0	76.5	77.0	1.53
Grade completed (years)					
Boys	3.6	3.7	3.1	3.2	1.70*
Girls	3.8	3.3	3.3	3.3	2.35**

*Figures are statistically significant at a level of 10%.

**Figures are statistically significant at a level of 5% or less. N_B and N_G represent numbers of boys and girls respectively

*** t-statistics of the difference in means of SHS and non-SHS households

4.9.2 Health Issues

The incidence of several types of preventable illness such as general ailment, respiratory diseases, and GI illness was lower among the members of the households that purchased a SHS. This lower incidence was found for boys and girls less than 15 years of age and as well as for men and women above 15 years of age. Note that the ownership of the system and regular usage of it may not directly help in reducing the occurrence of these types of diseases. But, the SHS that has the capacity to run a black and white TV and that actually the use of one may help reduce such incidence as various TV programs indirectly and a few commercials directly inculcate the prevention procedures of a few endemic diseases. Figs. 4.2 and 4.3 show clearly that in SHS households where there is a TV, the incidences of certain diseases are in fact lower.

Figure 4.2: Incidence of Illness among Children (age<15) in SHS Households by Availability of TV

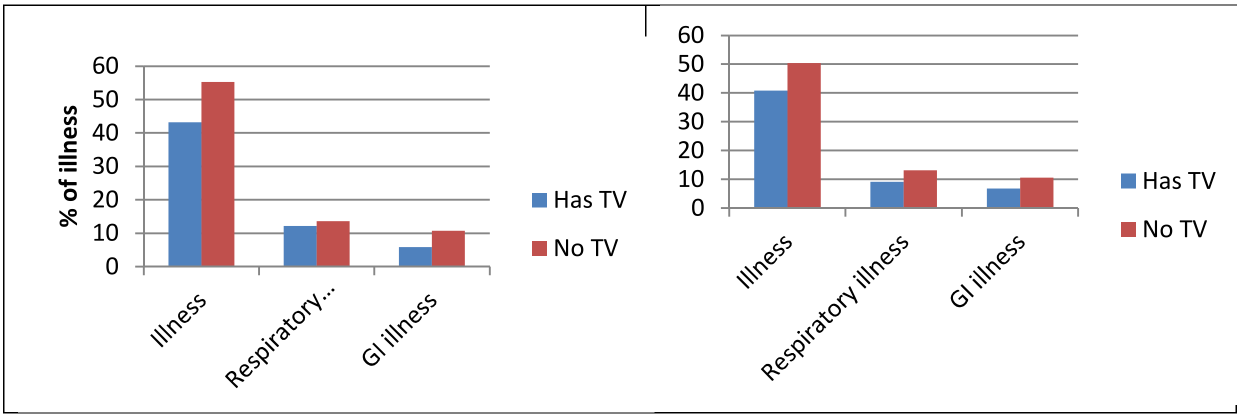
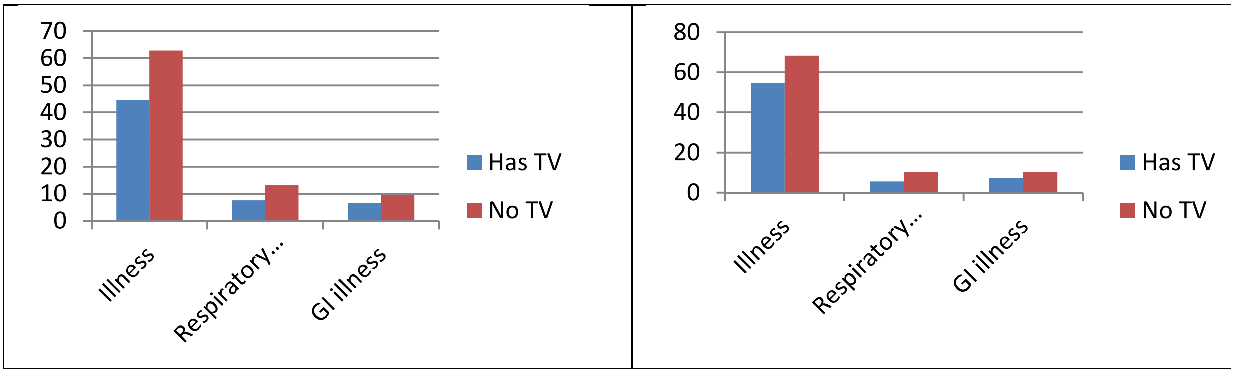


Figure 4.3: Incidence of Illness among Adults (age>=15) in SHS Households by Availability of TV



The married couples in households that purchased a SHS that is capable of running a black and white TV can spend extended hours in the evening in watching various TV programs some of which may inculcate about maternal and child health. Thus, the twin factors of extended hours staying awake and concern about the maternal and child health may be positively correlated with the adoption of the SHS. The findings of the study corroborate the above proposition as will be shown in Chapter 5 although only in a limited manner.

It may be noted that one needs to wait for a couple of years more to gauge the nature and extent of heterogeneity of impacts. Further, while we have chosen SHS villages on the basis of having earliest SHS connection for at least 3 years, the average length of time of acquisition of SHS is 2.46 years. Seventy nine percent of those in the sample have connectivity for less than 3 years with a mean of 1.73 years and for those connecting for more than 3 years is 5.26 years. For most of the SHS users therefore even if the intended impact may happen regarding health or education, more time may be needed for the relevant factors to play their role. Then again, the technology has changed within the last few years and that is already having some impact on the capacity demanded and consequent changes in other spheres of human activity.

Further, for some of the possible impacts the pathways may be quite complex as may be in case of health improvement. Households' living and work environment (sanitation and water supply and quality may be a major factor) may determine to a lagre extent the incidence of illness and its type. Access to health facilities also may be a factor. It would thus be quite an involved exercise while one may also object to the idea of bringing in factors which are actually external to SHS. In any case, simply looking at the length of experience of SHS may not be enough. It would thus be quite difficult at this stage of dynamic disequilibrium to investigate such impacts properly.

4.10 Gendered Dimensions of SHS Households and Apparent Impacts

Gender or the distinct social roles assigned to women and men, is a critical part of all development initiatives. A gender analysis is not a special focus on women, but rather, an understanding on how discrimination against women and gender roles interact to shape men's and women's enjoyment of human dignity, rights, as well as quality of living. In the context of installing SHSs in Bangladesh, a "gender analysis" promotes an understanding of the differential preferences for energy usage between men and women, of the ways that men and women are differently impacted/benefitted (if any).

4.10.1 Synergy between Technology and Women

Women have been one of main target beneficiaries of SHS programs by different POs. It is expected that women traditionally responsible for household energy needs have been rescued from this burdensome task by installed SHSs. In thousands of rural homes, women no longer need to clean kerosene lamps every evening and can finish their household activities more easily and in less time. It is likely that they feel more secure after dusk and can be more mobile.

Given the particular economic, social and reproductive (biological as well as social) roles expected of women in a typical rural household in Bangladesh, the impact of any intervention that affects or changes the work environment within the household is likely to affect men and women differently. Women are an effective force for economic development and they can play an important role in rural electrification as users and providers. At present, opportunities for women in rural Bangladesh as energy service providers are, however, extremely limited, and therefore the potential remains unfulfilled. Yet rural women are a natural choice for such services as they represent the largest group of rural energy users, particularly of biomass fuel for daily cooking.

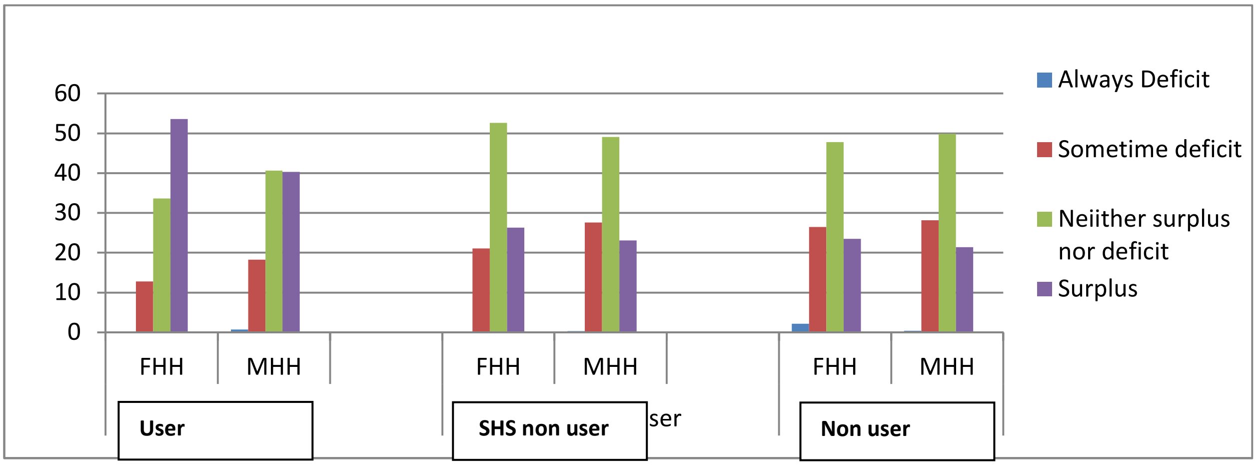
As users of energy services from SHS, women may be profoundly impacted as their timing of household chores may change due to availability of better lighting, study periods of female students may change while cooking itself may also be done late in the evening (if the kitchen has light points from SHS) rather than everything being done hurriedly in semi-darkness which may affect nutritional quality of the food that is prepared. Also, involvement of women within SHS user households in income generating activities or involvement in non-farm activities may be enquired.

4.10.2 Target Households for SHS Installation

Among the adopter households preponderantly 92.2% are male headed. Among SHS user households, 40.8% female heads do not have any education while this number is 25.9% for that of male headed households. However, on an average, completion of schooling years for 1-5 years is the most prevalent trend for both female heads and male heads. This scenario is also common in the households from control villages.

The selection criteria of HHs for installation of SHS are examined through household economic condition, among others. Food security round the year has been considered as an important indicator to depict the respective economic status of the households. Depending on the household food security situation, most of the users in female headed households (53.6%) have surplus during the year, whereas this corresponds to 26.3% for non user female headed households in SHS villages. There is a tendency not to sell SHS to food deficit households. Among user households, 93.9% of the female headed households do not have any food insecurity round the year, whereas for male headed households this stands at 74.2%. This is indicative of the fact that POs opt for relatively well to do households as clients keeping in mind the ease of payment, and it is more evident in case of female headed households. Extreme poor households are commonly excluded from SHS services. For wider coverage of rural energy through SHS, approaches need to be developed how to address these extreme poor households, along with special focus on extreme poor female headed households.

Figure 4.4: Food Security of HHs in SHS user, SHS non user and Non user HHs



4.10.3 Possession of Assets by Female Members

In terms of possessing resources/assets by female members in the households, SHS users, non-users in SHS villages and non-users in control villages do exhibit almost the same trend with regard to ownership of milching cows, cows, calves, goats, lambs, chicken and ducks. However, the total land values possessed by female members in user households are marginally higher than that for non-users in SHS villages and non-users in control villages.

Only 3.7% women in SHS user households possess milching cow, while this rate in non-user households is 4.5%. In about 60% cases, the value of milching cows possessed by the women in SHS user households is between Tk. 17,000 and Tk. 30,000; while in about 66% cases milching cows possessed by the women in non-user households the value is less than or equal to Tk. 25,000. More than 50% of the households possess chicken/ducks by female members in both types of the households.

Women in only 15% SHS user households have their own land property, while women in 9% households among non-users in SHS villages possess land. This fact is common in 11% households in non-users in control villages. In SHS households, where the land property owned by women, in about 57% cases the value of the land lies between Tk. 25,000 and Tk. 200,000. In top 10% households the value is more than Tk. 495,000. In contrast, the land value possessed by the women in non-user households in about 74% cases ranges between Tk. 30,000 and Tk. 200,000. Thus, women from SHS households possess higher worth of land property. The value of total land possessed by female members in user households might not reflect better empowerment by women in itself. However, it might be an attribution to the fact that, POs opt for better and well to do households as their clients.

Further analysis indicates that that in terms of possessing land, jewelry, deposits with financial institutions/NGOs and total value petty cash in hand by women, the user households are in better position than non-user households.

4.10.4 Women Empowerment: Participation by Females in Decision-making

The most general outcome albeit most difficult to measure of the adoption of the SHS is the extent of women empowerment. As most of the systems of the SHS support the load of a black and white TV, it connects the rural women to the rest of the world and inculcates in them ideas on various rights that the national constitution has enshrined for them. Besides, the access to TV also enables them to closely observe the customs and rights that women in other society practice and thus helps them reshape their rights and customs. Women empowerment is expected to increase with the access to the TV enabled through the SHS.

The electricity generated through the SHS opens the door of entertainment to the households, especially its female members. It was found that the availability of electricity helps women to read/study for their own pleasure or purpose. They can also get away with their boredom by watching TV or listening to radio. Besides, they devote more time to help their ward in preparation of their academic study.

Participation of women members in different types of decision making within the family has been enquired in terms of women's freedom of mobility, participation in household and economic decision making. Personal autonomy and awareness and other rights have also been assessed in terms of legal and other rights among different types of households in terms of energy usage.

In case of women's freedom of mobility expressed as participation of decision making in visiting parental home, going to shopping in the market place, visiting friends and relatives and going outside the village, the women from SHS user households have shown slightly better performance in decision making process. While the rate to decide by herself is higher in SHS households than those for non- user households, the tendency to make the decision jointly with father/husband is higher in non-user households. In case of going to parental house, female members from the 21.9% SHS user households is found to be self dependent, while 18.5% cases in non-user households from control villages female members are dependent on either husband's or father's choice.

In cases of decision for arranging matrimony for family members, solving family problems, purchasing expensive items such as land, purchase of child's healthcare, purchase of food items, purchase of children's education, the rate of incidence to take decision by female members are quite low. However, in cases of decision making where not much money is involved, for example freedom for mobility, the rate of decision making by female members are higher, however, all these decision making process are predominantly controlled by the male members of the families, for all types of households.

However, decision in national election has been largely taken by them, though the decision to participate in local election is quite influenced by their respective husbands. It is evident that awareness regarding the rights of female members has been acknowledged by most of the interviewees, irrespective of type of SHS usage.

Some of these empowerment issues have been probed with more rigorous econometric techniques in the next chapter. The analysis there clearly points to the gains in terms of empowerment that women may have made possibly through the awareness raising mechanisms through the electronic media.

4.10.5 Time Use Pattern among Different Energy User Types

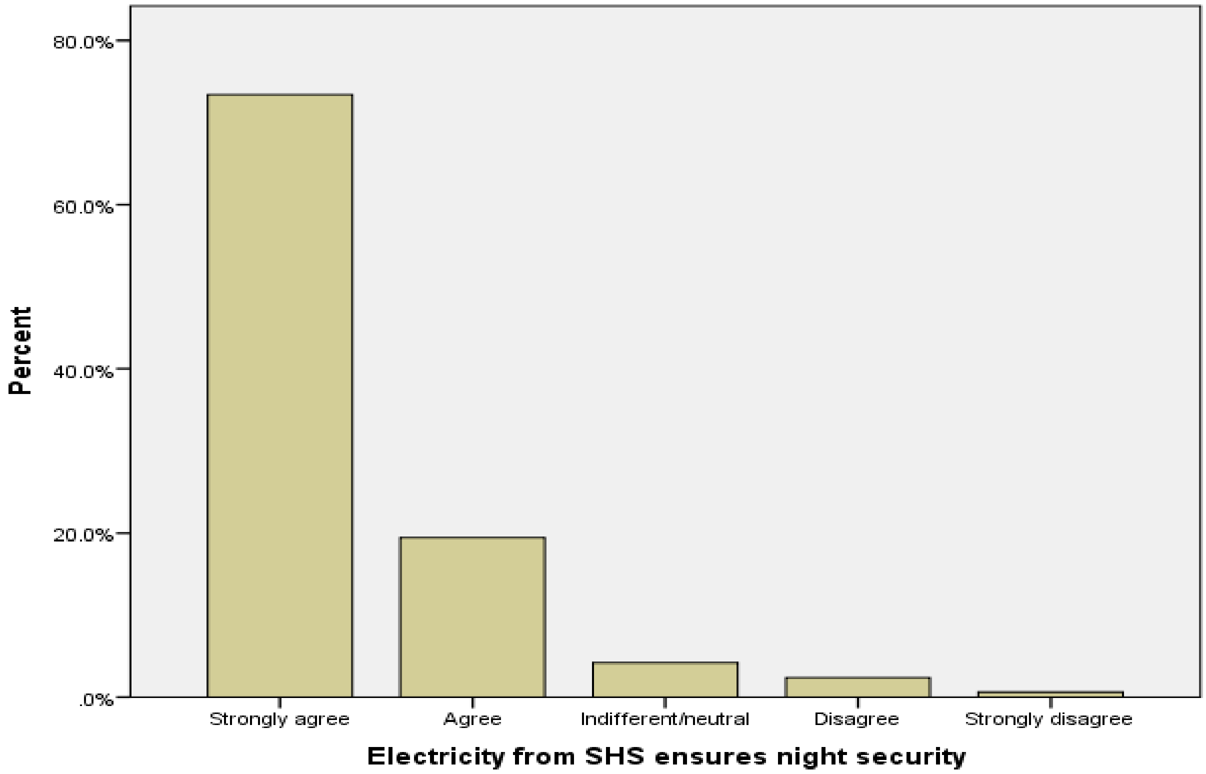
The collection time for fuel is significantly shorter for SHS users as compared to that for both non-users in SHS villages and non-users of control villages. This, however, probably cannot be attributed to SHS use as power from SHS does not substitute for the energy services (for cooking) for which fuel wood is used. It is probably more likely that because SHS users are economically better off they buy the fuel wood rather than collect it by themselves.

In any case, as women are primarily responsible for fuel collection, shorter fuel collection time may contribute towards other increased involvement by women in different activities which may be helped due to SHS. Thus, the time for tutoring children, watching TV, socializing, and visiting friends and neighbors have significantly increased for SHS users.

4.10.6 Sense of Security at Night

Most of the SHS user households agrees with the fact that SHS connection enhances night time security. Replacing kerosene lamps by SHS light connection provides better and in most cases cost effective lighting for longer time at night. This attributes to the fact that SHS user household members have higher sense of security at night time.

Figure 4.5: Night Time Security Issue



4.10.7 Information Regarding SHS

Among SHS users, incidence of getting knowledge about the SHS from neighbors rather than from POs is higher both in female and male headed households. However, the incidence is marginally higher for female headed households (65.6% for female headed households vis-à-vis 53.5% for male headed households). It seems that POs reach out to the male headed households in a greater number than that for female headed households as only 28.8% of the female headed households have been informed about SHS from POs as against 40.7% for male head households.

4.10.7 Fertility and Use of Contraceptives

Fertility and contraceptive use are complex socio-cultural behavior and there are both demand and supply factors. Unfortunately, we did not have information on supply of contraceptives through any population regulation program to the sample households which could tell us if control groups have any ease of access to such services. On the other hand, through TV and radio, women in SHS user households may have information about fertility regulation measures and that may help shape their relevant behavior. Yet, there are other factors such as education of the women involved, the desired family size, length of married life and the age of the particular woman all of which in truly interactive way finally shape the fertility and reproductive behavior. Just looking at the contraceptive use rate and fertility during last few years may not give us adequate information regarding changes in reproductive behavior. We therefore refer the reader to the relevant PSM exercise in Chapter 5 which shows that married women in SHS user and non-user households do differ statistically significantly in reproductive behavior. But as the reader will find the issue has not been resolved entirely satisfactorily.

4.10.8 Kitchen Lighting

It is expected that users of SHS, especially those households that have connection in kitchen, enjoy better indoor environment and are protected from indoor air pollution, which is one of the main reasons for women's suffering from diseases such as asthma, cancer, pregnancy related problems, still births, etc.

Interestingly, among users the rate of SHS connection to the kitchen is higher for female headed households (49.6%) than that for male headed households (39.9%). It depicts the differential preferences of usage by different sexes. Although all the household members are the users of the SHS, however, when the decision for preferences for differential usage is made by different sexes, the distribution for connection for different usage differs.

4.10.9 Disease Prevalence among Men and Women in Adopter and Non-adopter Households

The health impact as already indicated above appears to be a result of the process of information dissemination through the electronic media, TV and radio. As have already been shown in sub-section 4.9.2, both men and women and boys and girls do experience lower incidence of disease in SHS households compared to non-adopters. However, note that the adopters are economically and socially somewhat better off than non-adopters. Hence the situation regarding disease prevalence may also arise due to the better economic situation and greater awareness due to higher levels of education. This issue thus needs to be probed more intensively for the pathways of health benefits of SHS.

4.10.10 Income Generating Activities

Most of the off-farm income generating activities (IGAs) are undertaken inside the household premise, irrespective of the user status of SHS. It may be surprising to find that the women from non-user households are more involved in IGAs than those for SHS user households. One reason may be that the SHS per se does not lead to or has not led to IGAs in general. *Second*, and probably more importantly, this may reflect the lower level of economic situation the non-users are in. As their economic condition is worse than adopters, they have to diversify their activities to make their ends meet.

4.10.11 Payment Pattern and Perception of SHS

Around 73% users (both in female and male headed households) never defaulted in paying any installment.

The incidence of not having a contract for after sale service is higher for female headed households than that for male headed households (20.8% vis-à-vis 6.5% respectively). It is indicative to the fact that POs take advantage from the lack of command exerted by female heads. In most cases (83.4%) at least one of the household members has received any training for repairing some parts of the SHS. The majority of the households (96.9%) do not perform any IGAs by taking advantage of the SHS.

Even though most of the households do not want to purchase an additional SHS, however the rate of not willing to buy one additional SHS is higher in female headed households (93.6%) than that in male headed households (89.8%). About 40.2% female headed households consider that the price of SHS is too high compared to 29.6% in the male headed households. About 68.4% of the female headed households have informed that additional connection of SHS will not serve their needs, while the same is true for 59.6% in male headed households. About 6% of the female headed households are not happy with the services provided by the POs, while dissatisfaction stands for 3.1% in male headed households. This is indicative to a need towards shifting or changing approaches by POs in terms of services and usage offered. Also, prices of SHSs remain an issue for the stakeholders, especially for the female headed households. Continued subsidies and softer loans can be offered primarily to the female headed households given their history of higher credit worthiness Having basic training for maintenance and repair of the SHS and getting warranty for after sale services become an issue in case of further social acceptance of SHS.

Women seem to be less aware than men with regard to the environment friendliness of SHS. The sense of purpose for having another SHS is quite different for male headed households and those for female head households. About 40% of the male headed households appear to be willing because of entertainment purposes while this stands at 62.5% in the case of female headed households. It is evident that female members often find SHS as a source of getting better entertainment.

Both male headed and female households acknowledge the support from SHS in cases of children’s education (54.7% vis-à-vis 62.5% respectively). Interestingly, about 87.5% of the female headed households are willing to buy another SHS because they think it gives them comfort in their lives, whereas only 45.3% of male headed households considers this as an important factor to decide for another SHS..

SHS users from both female headed and male headed households strongly agree that SHS are needed for better education of their children as their children can study for extended hours at night, and it is more comfortable to study with solar light. However, respondents from the female headed households (80.8%) clearly indicate that they receive information about outside the world taking advantage of SHS compared to 75.2% in the male headed households. It might be the case that male members get information from outside home. But as women are constrained in mobility by social norms, SHS is a window to connect to the world with the help of connecting TVs, radios or mobile phones.

Women have exhibited less enthusiasm regarding the prospect of smoke free houses because of SHS than males as (75.2% vis-à-vis 80.8% for female headed and male headed households respectively). This is not surprising as SHS does not replace traditional cooking stoves. Other than providing lights it does not address the aspiration for smoke free environment at home. In about 87.2% of the female headed households the sense of security is higher at night because of SHS connection, however, about 72.2% of the male headed households strongly agree on the issue.

4.10.12 Empowering Women through Providing Technical Skills

Most of the POs in the program aims at addressing rural women as major stakeholder. It is evident from their documents that they envisage a mission to empower rural women through providing them technical skills on repairing SHSs. The Grameen Shakti (GS) plans to use the Grameen Technical Centres (GTC) to meet the projected demand for repair/maintenance services and SHS accessories at affordable costs. The GTCs aim to train women technicians and use them to produce the accessories. According to the official website of the GS, they also strengthen and expand the back-up services at the local level.[14] The GS also uses the GTCs to train women members from the user households as the organization feels that the women will be able to look after the SHSs because in Bangladesh, they are responsible for managing household activities. About 3000 women technicians have already been trained with funding from the USAID, many of them are assembling SHS accessories at local GTCs, others are providing after sales service.

Different service providers have mentioned repeatedly in their documents that SHS would enhance women empowerment and create income opportunities for them. However, no such specific initiative (other than providing training to women) is noticed after exploring their website, or interviewing the POs. They do not have any specific gender strategy specific to SHS. POs face difficulties in hiring women as the employees as sometimes they

[14] See *http://www.gshakti.org/index.php?option=com_content & view=article&id=79&Itemid=68*.

have to commute from remote areas and over long distance. Women's additional empowerment and income benefits thus have remained more or less statements only, not realized in practice.

4.10.13 An Issue for Clearer Focus

The discussion in sub-section 4.10 as well as in earlier and later chapters does bring out a few points regarding installation and operation of SHS vis-à-vis of women. These are: (i) female headed households are more receptive to the SHS adoption; (ii) women's education plays a very positive role in terms of adoption in households (whether female-headed or not) and choice of higher capacity SHS and whether kitchen is lighted by solar power or not is also to a considerable degree dependent on if women are decision-makers (as household head). On the other hand, POs apparently do not target households on the basis of such considerations. In some cases, particularly Grameen Shakti, women are also targeted for training (but not in case of all POs). Thus women seem to be trying to make the most out of a new situation involving technology despite various problems. How IDCOL and POs should respond to this by way of targeting women rather than regarding them as passive recipients of a new technology needs to be closely debated and practical solutions should be found to help women to help themselves.

Why should educated women demand more of SHS connectivity and of higher capacity? It is difficult to make any speculative hypothesis at this moment due to lack of appropriate information, some of which may be of sociological nature. But given that women behave that way, it has been proposed that IDCOL and POs should find out how women's positive role in adoption and operation of SHS may be supported through more attention to women's demand for energy service.

CHAPTER 5

IMPACT ASSESSMENT OF THE SHS

5.1 Design of the Impact Analysis

While a comparison of means and frequencies provides us with a preliminary set of insights into the impacts of the adoption of the SHS in relation to different dimensions of outcomes, these relationships are likely to be mediated by other aspects of household characteristics, which may dilute, confound, or exaggerate the actual relationship. For instance, the higher gender empowerment of the women or that children devote more time to study in the evening in the SHS households may be shaped by the special socio-economic characteristics of those households and not by the intervention.

Impact evaluation involves comparison of outcomes of beneficiaries to what those outcomes would have been had there been no intervention. Hence, it is necessary to construct a counterfactual measure of what might have happened without the intervention. All impact evaluation strategies need a method for constructing a proxy for these counterfactual outcomes from information on non-beneficiaries. This requires controlling for the effects of confounding economic and contextual factors that make program beneficiaries systematically different from an average non-beneficiary. These confounding factors can include the household characteristics (e.g., demographics, skill levels, or social networks) that affect the impacts of the program. Impact estimates that imperfectly control for these confounders suffer from “selection bias”.

Successful impact evaluations hinge on finding a good comparison group. There are two broad approaches that researchers resort to in order to mimic the counterfactual of a treated group: (a) create a comparison group through a statistical design, or (b) modify the targeting strategy of the program itself to wipe out differences that would have existed between the treated and non-treated groups before comparing outcomes across the two groups.

Since no baseline data are available for the treated farm households, the use of difference in difference method of assessment is not applicable. The above constraint limits the choice to the three contending non-experimental methods available for ex-post impact evaluation: (i) instrumental variables (IV), (ii) regression discontinuity design (RDD), and (iii) propensity score matching (PSM).

It may be noted that program placement - the choice of upazilas - is endogenous. However, once an upazila is selected, all of the households are eligible to buy SHSs. It may also be noted that the IV method involves finding an instrument that is highly correlated with program placement or participation but not correlated with unobserved characteristics affecting outcomes. However, finding instrument for SHS adoption is a formidable task as is for any other endogenous variable. Besides, if the instruments are weak in the sense that they are marginally significant, it will cast doubt about the strength of these instruments and consequently the results (Bound, Jaeger, and Baker, 1995). The issue of instrumental variable regression was seriously considered as an alternative but could not be implemented due to lack of identification of meaningful and valid instruments. Further analysis may be done using this alternative method when more information either panel or valid instruments are available.

Unlike micro credit programs, where targeting is based on land ownership or gender attribute of the household head there is no definitive criterion for targeting SHS households. This is a demand-driven program where POs sell SHS to a customer (in an off-grid area) who has the willingness and ability to pay for the SHS. The lack of definitive criterion for targeting rules out use of RDD method as SHS purchase is not determined by an explicitly specified exogenous rule such as the one used for micro credit targeting in the country. As there are no cut-off points, there are no such households around the cut-off point for eligibility. Hence, households just on the other side of the cut-off point cannot be used as the counterfactual in the absence of a cut-off point.

As the above two methods fail, one needs to appeal to the PSM method to match program participants with non-participants typically using **individual observable characteristics**. In this case, each SHS household is paired with a small group of non-participants in the comparison group that are most similar in the probability of participating in the program. This probability (called propensity score) is estimated as a function of individual characteristics typically using a logit or probit model.

Methods available for impact evaluation are often context and data specific, not all methods are suitable to all types of data. Whatever the method be, credible assessments of program impact require that program beneficiaries (the “treatment group”) are as comparable as possible to those not receiving benefits from the program (the “comparison group”). In what follows is a succinct description of the propensity score matching (PSM) method used for assessing the impact of SHS on the participating households.

The PSM method constructs a control or comparison group by “matching” treatment group SHS households to comparison group of non-SHS households based on observable characteristics. Using matching on observable characteristics, one could potentially reconstruct hypothetical values on outcomes in the absence of the program assuming that all observable characteristics accurately capture and predict outcome of an individual SHS household. The impact of the program is then estimated as the average difference in the outcomes of treated SHS households and comparison group of non-SHS households from the matched sample.

PSM methods compare treatment effects across participant and matched nonparticipant units, with the matching conducted on a range of observed characteristics. PSM methods therefore assume that selection bias is based only on observed characteristics; they cannot account for unobserved factors affecting participation.

Following Heckman, Ichimura, and Todd (1997) and Smith and Todd (2001, 2005), let Y^1 be a farm household's outcome if it is a recipient of program benefits and let Y^0 be that household's outcome if it does not receive any program benefits. The impact of the program is just the change in the outcome caused by receiving benefits: $\Delta = Y^1 - Y^0$. However, for each household, only Y^1 or Y^0 is observed. Let D be an indicator variable equal to 1 if the household receives program benefits and 0 otherwise. In the literature on evaluation of social programs, D is an indicator of receipt of the "treatment." We construct an estimate of the average impact of the project on those that receive it—the average impact of the treatment on the treated (*ATT*):

$$\mathrm{ATT}=E(\Delta|X,D=1)=E(Y^1-Y^0|X,D=1)=E(Y^1|X,D=1)-E(Y^0|X,D=1) \qquad (1.1)$$

where X is a vector of control variables.

Insofar as $E(Y^0|X, D=1)$ is not observed, the impact of SHS intervention on outcome indicators can be estimated using PSM as a method for estimating the counterfactual outcome for participants (Rosenbaum and Rubin 1983). Let $P(X)=\Pr(D=1|X)$ be the probability of participating in the program. PSM constructs a statistical comparison group by matching observations on beneficiaries to observations on non-beneficiaries with similar values of $P(X)$. However, the validity of this approach rests on two assumptions: (i) $E(Y^0|X,D=1)= E(Y^0|X,D=0)$, and (ii) $0 < P(X) < 1$.

Expression (i) assumes "conditional mean independence," that conditional on X non-participants have the same mean outcomes as participants would have if they did not receive the program. Expression (ii) assumes that valid matches on $P(X)$ can be found for all values of X. Rosenbaum and Rubin (1983) show that if outcomes are independent of program participation after conditioning on the vector X, then outcomes are independent of program participation after conditioning only on $P(X)$. If (i) and (ii) are true, PSM provides a valid method for estimating $E(Y^0|X, D=1)$ and obtaining unbiased estimates of *ATT*.

Through comparisons with experimental estimators, Heckman, Ichimura, and Todd (1997, 1998) show that PSM provides reliable, low-bias estimates of program impact provided that (i) the same data source is used for participants and non-participants, (ii) the data include meaningful *X* variables capable of identifying program participation and outcomes and individual variables pass the so-called ‘balancing test’. As will be detailed later, the survey was implemented in 64 villages (32 with intervention and an equal number without intervention) for the SHS evaluation. Hence, criterion (i) has been satisfied. Further, the survey includes a sufficiently rich set of variables to identify program participation and outcomes related to project objectives, therefore, criterion (ii) has been satisfied as the results of the ‘balancing test’ suggest.

The use of the PSM technique for assessing impacts of the SHS intervention involved several steps: First, the propensity score for participation in the program was estimated using a probit model. Second, the “balancing properties” of the data were assessed by testing that treatment and comparison observations had the same distribution (mean) of propensity scores and of control variables within groupings of the propensity score. Control variables that do not satisfy this test were dropped or replaced with alternative variables and the specification was rechecked. All impact results presented in this study are based on specifications that passed the balancing tests. Third, the “common support” was applied following Heckman, Ichimura, and Todd (1997, 1998) to improve the quality of the match by ensuring that matches are formed only where the distribution of the density of the propensity scores overlap between treatment and comparison observations. Typically only comparison observations are dropped in the left of the distribution and treatment observations are dropped in the right. Fourth, the treatment observations from the interior of the propensity score distribution that had the lowest density of comparison observations (i.e., lowest common support) were dropped to improve the quality of the match.

On this common support sample, the probit model was estimated again to obtain a new set of propensity scores to be used in creating the match. The distribution of propensity scores for the comparison group often lies to the left of the distribution for the treatment group for targeted programs, such as the SHS program. As a result, the highest propensity scores tend to come from treatment observations, while the lowest are dominated by comparison observations.

5.2 Estimated Outcomes of SHS Adoption by Households

The SHS intervention expected various qualitative and quantitative outcomes. Some of the outcomes include: (i) duration of school going children’s study in the evening, and years of schooling completed by them, (ii) contraceptive prevalence and fertility among currently married women, (iii) women empowerment, and (iv) kerosene replacement. Among these the issue of kerosene replacement has already been analyzed in Chapter 4. The rest will be analyzed here.

5.2.1 The Probit Model

Table 5.1 presents the estimates of the probit model. These covariates were used to predict probability for the purpose of propensity score using kernel and nearest neighbor matching. All of the coefficients except electricity connection are statistically significant. While many of the covariates were statistically significant, the precision rates of the other covariates were very low.

Table 5.1: Probit Estimates of Household Adoption of SHS in Bangladesh

Name of Selected Explanatory Variables	Household Adoption of SHS	Mean and Standard Deviation of Explanatory Variables
Age of household head (years)	-0.0005** (-4.21)	46.1 (12.9)
Sex of household head (M = 1, F = 0)	-0.022** (-2.91)	0.943 (0.232)
Highest education among household males (years)	0.001** (3.82)	4.58 (4.43)
Highest education among household females (years)	0.001** (2.85)	4.14 (3.84)
HH size	0.002* (1.85)	5.08 (1.87)
HH head is self-employed (1=Y, 0=N)	-0.001 (-0.30)	0.654 (0.476)
Housing structure is brick-built (1=Y, 0=N)	0.048** (3.58)	0.030 (0.171)
HH uses improved toilet (1=Y, 0=N)	0.007* (1.97)	0.360 (0.480)
HH has improved water supply (1=Y, 0=N)	0.010** (2.35)	0.409 (0.492)
Log HH land asset (decimals)	0.004** (2.83)	121.0 (220.4)
Log HH non-land asset (Tk.)	0.008** (5.90)	1,830,573.0 (6,687,751.0)
Village price of fuel wood (Tk./kg)	0.0004 (0.10)	4.21 (1.41)
Village price of dung (Tk./kg)	0.001 (0.18)	2.95 (0.66)
Village price of kerosene (Rs/liter)	-0.004 (-1.58)	64.91 (1.81)
Village has primary schools (1=Y, 0=N)	0.029** (2.45)	0.689 (0.463)
Village has secondary schools (1=Y, 0=N)	0.010 (1.05)	0.255 (0.436)
Village has paved road (1=Y, 0=N)	-0.010 (-0.92)	0.546 (0.498)
Village has GB (1=Y, 0=N)	-0.013 (-1.16)	0.702 (0.457)
Village has BRAC (1=Y, 0=N)	0.023** (2.33)	0.787 (0.410)
Village has other NGOs (1=Y, 0=N)	0.012 (1.02)	0.745 (0.436)
Village is in *char* area (1=Y, 0=N)	0.055** (3.23)	0.253 (0.435)
Village is subject to river erosion (1=Y, 0=N)	0.048** (2.48)	0.183 (0.387)
R^2 or pseudo-R^2	0.196	-

Note: Marginal effects are reported. Figures in parentheses are t-statistics based on robust standard errors (corrected for village level clusters), except for the last column where they are standard deviations. * and ** refers to a significant level of 10% and 5% or better respectively. Explanatory variables include, in addition to those reported here, village level price of consumer goods and wage. Moreover, division level dummy variables are included to control for unobserved bias at the division level.

5.2.2 Matching of Adopter and Non-adopter Households

Table 5.2 and Fig. 5.1 show the distribution of households within and beyond the common support of PSM estimation. It may be noted that less than 1 percent of the SHS households and less than 2 percent of the non-SHS households fall outside the common support. This implies that most of the households with or without SHS status share similar observed characteristics as have already been discussed in earlier particularly in Chapter 3. Thus, one can take the ensuing PSM estimates with more confidence.

Figure 5.1 which is the graphical interface of Table 5.2 further shows that the SHS households and the non-SHS households off common support fall respectively to the right and left of the distribution as postulated above.

Table 5.2: Distribution of HHs by Common Support from PSM estimation

SHS adoption status	Within common support	Off common support	Total
SHS HHs	1,589 (99.3)	11 (0.7)	1,600
Non-SHS HHs	2,361 (98.4)	39 (1.6)	2,400

Note: Figures in parentheses are percentages of households within and off the common support among SHS and non-SHS HHs.

Figure 5.1: Distribution of HHs by Common Support from PSM estimation

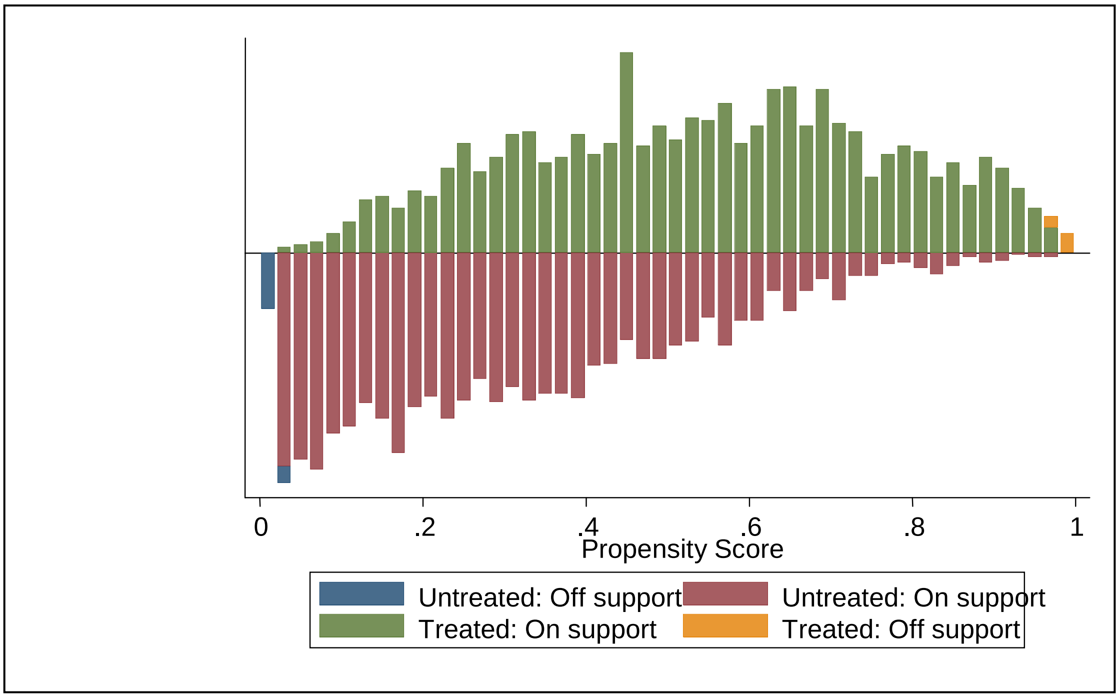


Table 5.3 shows an assessment about the balancing quality of the PSM. The balancing test provides further corroboration about the validity of the PSM. While the extent of standardized bias was about 17percent before matching, it came down to about 5 percent after matching. Thus, about 68.5 percent of the pre-matching bias would be removed in the matching estimates.

Table 5.3: Assessing Quality of Balancing in PSM estimation

	Standardized bias	Bias reduction (%)
Before matching	16.694	68.5
After matching	5.265	

5.2.3 Educational Outcomes

As mentioned earlier the main channel through which SHS provides educational benefits is the longer study hours for school going children at home due to bright light without indoor air pollution. This may subsequently increases their chances of completing higher levels of education. Table 5.4 shows the PSM results of the impact of SHS on these outcomes.

Table 5.4: Estimates of SHS Impacts on Children's Educational Outcomes (age 5-18)

	Nearest neighbor matching		Kernel matching	
	Evening study time (minutes/day)	**Schooling years completed**	**Evening study time (minutes/day)**	**Schooling years completed**
Boys	8.48** (3.17)	0.04 (0.23)	7.30** (7.73)	0.0004 (0.01)
Girls	12.12** (4.10)	0.259 (1.40)	10.91** (3.99)	0.21 (1.27)

Note: Figures in parentheses are t-statistics. ** refer to a significance level of 5% (or better). PSM probit regression includes individual, household and village level control variables such as age, head's age, head's sex, maximum education of adult males in the household, maximum education of adult females in the household, log of household land asset, log of household non-land asset, village prices of alternate fuels and consumer goods, various village infrastructure variables such schools, road, bank, and so on, village wage, and state or division dummies.

It may be noted that school going children in the SHS households study about 8-12 minutes longer in the evening compared to the school going children in households without SHS with the difference more for the girls than for boys under either types of matching. However, this longer duration of study did not translate into significantly higher levels of education. One of the reasons for the lack of manifestation of the latter outcome may be the shorter duration of time these children have had as most of the systems were installed only in recent years and in many cases for less than 3-4 years.

5.2.4 Reproductive Behavior

Table 5.5 shows the PSM impact of contraceptive prevalence and recent fertility among the currently married women in the SHS. The kernel matching implies that contraceptive prevalence rate increases by about 1 percent whereas the nearest neighbor matching shows that it decreases by about the same percent. While the impact in the former type of matching is not significant, it is significant in the latter type. In contrast, the access to TV and radio as "alternative to sex" for recreation was found to be negatively related to SHS under both the types of matching. This evidence implies that access to TV courtesy of the SHS enhances awareness of the married women about maternal and child health issues and thus indirectly affects the reduction in fertility. The extent of fertility reduction was found at 0.07-0.10 depending on the type of matching used. The magnitude is not too far from 0.15

which was found in the case of rural electrification (World Bank, 2008) even though the methodologies employed in the two studies differ.

The contraceptive prevalence rate and fertility decline as analyzed above appear not to be completely consistent with each other and needs further probing. It may, however, be noted that the activities refer to two different time period. The contraceptive prevalence rate refers to current behavior while the fertility refers to the three years prior to the survey. Thus, these may not completely be dovetailed with each other. in any case, this is an important issue which needs to be more thoroughly investigated in later research. reproductive specific time periods.

Table 5.5: Impacts of TV Ownership by SHS Household on Married Women's Reproductive Behavior (Aged 15-49)

Reproductive outcome	Nearest neighbor matching	Kernel matching
Contraceptive prevalence rate	-0.009** (-0.29)	0.008 (0.30)
Recent fertility	-0.098** (-2.58)	-0.073** (-2.09)

**Figures are statistically significant at a level of 5% or less.

5.2.5 Women Empowerment

Table 5.6 shows the PSM impact of SHS on women empowerment. It may be noted that in all three indicators considered, the women in households with SHS enjoy higher level of women empowerment than those in households without SHS. As mentioned earlier the solar electricity per se does not affect the level of women empowerment in general. However, the black and white TV enabled by it is likely the conduit for such outcomes.

Table 5.6: Estimates of SHS Impacts on Women's Empowerment Outcomes (Married Women of 15-49 Years)

Empowerment outcomes	Nearest neighbor matching	Kernel matching
Mobility		
Go to parents' place	0.041** (2.24)	0.024 (1.41)
Go to relatives'/friends' place	0.026* (1.66)	0.012 (0.86)
Go to other outside places	0.029** (2.59)	0.009** (2.60)
General Decision making		
Decide on children's issues	0.013** (2.30)	0.012** (2.21)
Decide on own health issues	0.070** (3.23)	0.057** (2.83)
Decide on family planning	0.028 (1.59)	0.021 (1.32)
Decide on other family issues	0.028** (4.20)	0.029** (4.40)
Decide on socio-political issues	0.013* (1.77)	0.008 (1.12)
Economic Decision Making		
Purchase of own goods	0.036** (2.72)	0.036** (2.72)
Purchase of household goods	0.014** (2.70)	0.014** (2.70)

*Figures are statistically significant at a level of 10%. **Figures are statistically significant at a level of 5% or less.

Social outcomes such as women’s mobility and decision-making may improve from increased awareness and exposure to information, which can be accumulated through electronic media such as TV. Our household data show that 37 percent of the SHS household own a TV set, which is probably why the social outcomes of women in SHS households have shown improvement compared to the households without SHS. This widening may in circumstances be conducive to women's additional employment (whether income earning or saving) provided such opportunities exist in the off-grid but SHS area. Further probing is necessary to understand who the women socialize with, whether they can serve as gateways to new economic opportunities and of course whether the SHS areas do have such opportunities in general. For this to be understood one needs more in-depth and broad-based information which are lacking at the moment. Note that while the community information provides some broad information, this is not enough. One needs to understand at least by upazila the prospects of new opportunities.

5. *3 A C*omparison with Rural Electrification Impact

One question that may come up while analyzing and drawing policy conclusions on the basis of observed impacts of electrification is whether grid-based electrification and off-grid electrification (solar homes in this case) do differ. It is not possible to do such a comparison in the present case for two reasons. *First,* we do not have off-grid and grid-based households in the same area as solar homes are only for off-grid areas. *Second*, even if we want to compare grid-based electrification impact with solar based impacts, this is not possible because the most recent impact evaluation of rural electrification examined mainly economic impacts in terms of income, expenditure and employment. (Murshid, et al., 2010) These were not estimated or probed in the solar home case here because the solar power in such systems is hardly used for direct economic activities. The only point of commonality is the study time of students and kerosene use. For whatever the reason, in the rural electrification case, the study times (total and night time) were found to be lower for the electrified households compared to the control. Similarly, kerosene use appeared to have increased which was explained by the degradation of the quality of supply of electricity over time.

CHAPTER 6

NATURE AND EFFECTIVENESS OF PO OPERATIONS

6.1 Introduction

The previous chapters have described and analyzed the household behavior and impact when a new energy technology has been presented to them. This refers to the demand side situation. In contrast, Chapter 2 has provided a macro overview of the supply side while the following chapter analyses how in future the households are expected to behave and how far the supply may be provided. In between one needs to know how things are actually happening on the ground. For this, we depend on primary survey data on PO field offices. As already mentioned, we had found 167 PO field offices operating in the 64 treatment villages. Our analysis is based on the reports received from these field officials of the POs. Some of the issues that they mentioned are verifiable with information from the households. This will be done as far as possible. Note that the technical issues will not be dealt with in this chapter; these are analyzed separately in chapter 8. The managerial and operational issues will be mainly discussed and analyzed in this chapter.

6.2 Whose Branches?

In the 64 SHS villages and among 167 field offices the following POs with their numbers and percentages of all surveyed field offices were found: Grameen Shakti: 44 (26%); Rural Services Foundation 30 (18%); Srizony Bangladesh: 18 (11%); BRAC: 8 (5%) and the rest 67 (40%). Among these in 28 (17%) branch areas, only one PO is operating which means that in other areas more than one are active. Of the POs having only one branch in an area, the following is the distribution: Grameen Shakti : 12; BRAC: 1; Srizony Bangladesh: 4; RSF: 2 and all others: 9. This means that there are several branch areas with more than one PO operating with the following distribution: 2 POs in 12 areas; 3 POs in 7 areas: 4 POs in 11 areas; 5 POs in 5 areas; 6 POs in 3 areas; 7 POs in 1 area respectively.

This shows that POs are operating in highly competitive conditions. While this means that there are likely to be high pressure selling tactics, whether that also means better quality services to households remains an open question. As will be seen later, the quality of technical backstopping service is probably not the best that one would expect it to be.

6.3 Who Runs the Branches?

Each of the POs has its own specific designation of posts. It was not possible to identify all of them by type of job and reclassify again to understand their functions. In general, many of them perform more than one function and it is difficult to put them in a clear niche. So, we have examined only a few of the designated posts which apparently indicate the type of job they do such as managers, accountants, technicians and field assistants. Some ideas of their background is given in Table 6.1.

It has been found that a large proportion of managers have some kind of formal technical educational background and that quite a few of them had worked for other POs in the past. The latter applies to most of the staff. It is difficult to assess whether they receive commensurate salaries and compensations given their background. Note however that some of them such as managers draw up to Tk. 24,000 per month in total emoluments which in an area outside the capital may seem a handsome one.

Table 6.1: Staff Characteristics of PO Field Offices

Post	Number	Education (%)	On-the-job training (%)	If previously in another PO?	Total monthly pay (Tk.)
Manager	162	HSC: 33; Graduate: 31;Diploma Engineer: 35	89	28	13,200
Accountant	12	HSC: 39; Graduate: 46	92	23	11,500
Technician 1	134	SSC: 68; HSC: 27	65	19	7572
Technician 2	63	<SSC: 33; SSC: 56	85	25	6430
Field Assistant	100	HSC: 87	83	23	9945

Source: Based on BIDS Survey, 2012

6.4 Years and Mode of Operation

6.4.1 Length of Operation

Most PO field offices have been in operations only for a few years although rather long period of operation is not totally absent. The average length of operations in many cases such as for Grameen Shakti is above 3 years with the maximum being 13 years. But for others, generally it is 2 years or less. We have earlier seen that most households have acquired their SHS units only during the last 2-3 years and that is because the field offices have been in operation only for a few such years.

6.4.2 Mode of Operation: Planning for and Getting a Client

Usually field offices have monthly sales target. However, these targets, of course, vary because of the size of the operations of the offices as well as the years of operations. Sales target for the Grameen Shakti field offices are the highest on average at about 34 per month closely followed by RSF at 31. The third highest is that of Srizony Bangladesh but at almost half of the Grameen Shakti at 18 or so. BRAC has the lowest at around 5. On an average a field office has a target of around 24-25 new clients per month, i.e., one each day on average which must be quite hectic for a small office with a manger, a technician or two. A few of these staff have to do the accounting job in addition as only a few branches have the luxury of a full-fledged accountant. While we have not probed the issue, perhaps around 15-16 would be a good target, i.e., one in 2 days per month. In fact, as reported by the field officials, it takes on average 3 days to install an SHS. That means, about 8-10 (counting holidays) may be installed on average in a month. Setting high targets may therefore be only a pressure tactics on the part of the PO head quarters.

Sales tactics are several including distribution of handbills and brochures, use the good offices of the local elites, approaching potential customers directly etc. These tactics may or may not vary across the POs. It was found that distribution of handbills is practiced roughly by half of the PO field offices as the most important approach followed at 30% for direct approach to the potential client. Local leaders' good offices are also used but comparatively much less at 16% of cases. Note that direct approach is probably more important when a PO field office begins its operations in an area and we find that in such cases, more than 40% of the sales effort is of this type, something like 'know your customers'.

The sales efforts apparently pays off as some 75-80% of the sales are reportedly due to such sales efforts while the rest is due to clients approaching on their own. However, the relative successes in the two situations are different: nearly 80-85% of targeted potential customers ultimately do buy an SHS. The corresponding rate for voluntary approach by clients is just around 50%. The proportions vary little across the POs.

Those whom the PO field offices approach directly, the criteria of choice, not surprisingly, is that they must have the means to pay back. This means that in practically all cases it is the wealthier section of households, those having steady jobs or remittance income are targeted in this manner. This approach is invariant across the PO filed offices.

6.4.3 Mode of Operation: Installation and Related issues

As has already been stated, it takes on an average 3 days or so to install an SHS. This period includes the time to explain the various features and operational instructions to the clients at the time of delivery. The time spent is not short as on average 2 to 2.5 hours are spent in explaining the system, its use and precautions and general maintenance issues by all POs. Whether this is good enough is difficult to say. It will be found later in the chapter on technical issues that households have been found to be complaining somewhat regarding the inadequacy of the explanations provided.

POs also provide training on minor repair works so that households do not have to call a PO technician for such works. As found, such training is universal for the GS and RSF clients, but not so much for others. Roughly in a third of cases field officials did not claim to have given any such training. Among those who are imparted training, it is predominantly the men, but so do women in 40% or so cases.

All of the POs make follow-up visits, but roughly only in 70% cases as scheduled while in the rest 30% cases at the client's request. Such visits take place on average after a week or so but some like BRAC the visit is usually after two weeks. On first visits, as reported by field officials, roughly 50-52% clients appear to understand well the operations of the SHS but for the rest there are some problems and again of them roughly one-half does not understand it at all. This shows that there may be need for a quicker follow up than is the practice or that the explanations and training need to be conducted more carefully and in simple language. In fact as a recent report on technical quality of installations indicate, there may actually be problems in installations, sometime of rather major deficiencies (KFW: undated). Thus, which way the problems actually lie need to be more clearly probed.

6.5 Operation of the Credit System

As already noted earlier the SHS are generally sold on credit. As the interest payments made by the households are a source of income to the Pos, they must be anxious to get their money back as quickly as possible. In most cases (80-85%) they do get repayments regularly but in some 10-12 % cases, there are problems of irregular payments while there are 3-5% delinquencies. One may note here two points. *First*, BRAC seems to have more problems (30% irregular payments and 13% delinquencies) than others, possibly because of its less frequent interaction with clients. *Second*, areas where the POs had been operating longer, the irregular payments and delinquencies are somewhat higher.

Borrowers who face problems in repayment are more often than not (88% cases) given a grace period to pay back the money. But there is some difference across the POs: Grameen Shakti is the most lenient about this as they provide a grace period reportedly in 96% cases while Srizony Bangladesh is comparatively more strict as it provides such grace period only in 83% cases.

On delinquency, however, Srizony Bangladesh is far more lenient than others. While on average, branch offices take back the SHS of the delinquent borrowers in 24% cases, for Srizony Bangladesh it is 33% while for the Grameen Shakti it is 82% while for RSF it is the lowest at 70%.

Delinquency may in fact be a problem.[15] Since their operations the sample field offices had a total of 3568 delinquent cases. Of this 1349 or near about 40% cases occurred during the last 12 months before the survey. This is indeed a serious matter. While the situation is serious for all POs, it is the most problematic for Srizony Bangladesh as half of its delinquencies occurred during the last 12 months.

In 16% of cases, the SHS was returned voluntarily by the clients and again the tendency had been stronger during the last one year or so. More worryingly, this has happened more for the branches where the set up had been not even a year. Of the 1752 systems returned, 627 were in areas where branches had begun operations for at most a year. Something must have been going wrong.

Clients stated various reasons according to the PO branch officials for the return of the systems. Among these, inability to pay back the credit taken was the most important reason cited (in about 2/3rd cases). A tiny minority, about 5%, thought that the costs do not justify the benefits they get.

In 87-88% cases, some money is paid back to the clients when they voluntarily return the SHS. The money so given amounts to more or less 75% of the money already paid by the client.

Three reasons (out of multiple responses) stand out as the problems of operation as stated by the PO branch staff: poor quality of lighting, charge controller problems and the batteries. These three account for 308 out of 369 reasons (i.e., 84%) given. Then again much of the problems appear to be experienced in more recently set up branch areas. This indicates that the problems are of generally poorer quality of the technology or its components, or of maintenance apart from the financial constraints faced by the households as well as possible managerial problems in the new branches.

The solutions to the problems were in general that the SHS and its components must be of high quality and also that quality training should be conducted to customers. These were in some cases, not all pointed out to the head quarters and some measures were reportedly taken for improvement. However given the nature of the answers, it seems that this issue of feedback from field and consequent follow-up needs to be investigated more properly.

There are also other concerns. While little local political interference was reported, many did complain of interference by government functionaries at local level. There is also interference by other POs operating in the area in about 30% cases. And again, of more

[15] Similar concerns have been expressed by the KFW (undated).

concern, this appears to be a more recent phenomenon as is observed mainly in recently established branches.

6.6 An Overall Assessment of Ground Operations

The over-all impression one gets here is that there is an almost standardized system of operations on the ground. Many of the rules and procedures are rather similar across the POs. So far it has worked fairly well. As increasingly more POs are starting operations in areas where others are also operating, the competition is getting tough. Instead of providing quality service, the tendency overall had been to compromise with it. This is evident from the performance indicators in more recently set up branches. Problems are beginning to pile up. PO branch officials themselves complain of poorer quality of SHS and its components while consumers also are blamed for some of the problems as roughly a quarter do not properly understand the operation of SHS. As a result, there had been voluntary return and also delinquency due to financial constraints and these are now beginning to accumulate. As Bangladesh has a very high potential for further expansion of the SHS, it is high time that before going into a vigorous scaling up, the problems should be managed well and not allowed to fester, If it does, again a very good Bangladesh initiative will falter as did several other institutional good experiments earlier such as the Comilla model or the early LGED initiatives.

CHAPTER 7

DEMAND FOR SHS, FINANCING AND THE SIZE OF THE MARKET

7.1 Preamble

The SHSs have been either sold on cash or credit under certain conditions between the IDCOL and the POs and between the POs and the household clients. Ultimately, however, it is the households that demand the SHS. Like most other demands, it is price sensitive, a price which depends on various elements such as level of subsidy and the rates of interest on credit. Such sensitivity of demand also means that there is a maximum potential size of the market under a given set of conditions. The policy makers need to know what that size of the market is and under what conditions. This chapter will try to estimate the demand for SHS under certain plausible conditions.

7.2 Estimation Method

Contingent valuation (CV) method has been used to estimate the willingness to pay (WTP) for SHSs for households living in off-grid areas. The CV questions used to elicit the WTP are shown below:

Case I: Applicable for the Existing SHS Users

You have purchased a ______ watt power (Wp) unit SHS for your home already. If you are asked to buy an additional SHS unit of choice ________ Wp, for which you have to pay Tk. ___________ as down payment and Tk. __________ as monthly installment for 3 years.

Will you be willing to purchase this unit?

Case II: Applicable for the Non-users

It is now possible to use SHS for light, charger fan and also running black and white TV in your house. This means that you need to purchase a SHS unit and its capacity will depend on its Wp. If you are given a choice to purchase _____Wp [which can be used for _ lights, and _ TV] for which you have to pay Tk. _________ amount as down payment plus a monthly installment of _______ for 3 years.

Will you be willing to purchase this unit?

These questions were designed to ensure that a) respondents do not have any level of confusion on the product, b) the prices given to each respondent was randomly chosen so that households respond to a randomly chosen price, c) the number of respondents for each price is also same so that the averages are not biased with number of respondents in each category.

Based on this, a probit model was used to estimate the probability of purchase at different prices. Income of the household and wealth of the household (measured as farm-size and housing structure) were used to control for income and wealth effect on demand for SHS. Survey results also show that many of the existing SHS users used the system in order to ensure education of their children. As a result, the number of school going children in the household was also used to understand its influence of demand for SHS or in Willingness to Pay (WTP). Further, households also provided their own reasons for purchase of SHS during the survey. Three most important causes for purchase of SHS are a) quality of light in the house for education of the children, b) convenience in using the SHS (against existing light using kerosene and others) – a proxy for life style, and c) need for entertainment including charging mobile phone and watching TV. Different explanatory variables were tested to determine the best model for explaining the probability of purchase of SHS. The final probit model is shown below (Table 7.1)[16]:

Table 7.1: Probit Estimates on the Purchase Decision on SHS based on CV Questions

Dependent Variable: Purchase (yes=1, no=0)						
Variables	Expected signs	Coefficient	sig	Marginal Effect	sig	Average
Price of SHS (000 taka)	(-)	-0.0419	***	-0.0152)	***	24.84
Dummy for Wp 40 (Wp 40 = 1)	(+)	0.3068	***	0.1157	***	0.14
Dummy for Wp 50 (Wp 50 = 1)	(+)	0.4946	***	0.1913	***	0.12
Dummy for Wp 65 (Wp 65 = 1)	(+)	0.6540	***	0.2559	***	0.11
Housing Quality Index †	(+)	0.3475	***	0.1244	***	0.98
No of Students in the Household	(+)	0.1775	***	0.0638	***	1.13
Farm Size ††	(+)	0.3068	***	0.1111	***	1.08
Need for Education (Yes = 1)	(+)	2.2577	***	0.6539	***	0.03
Need for entertainment (Yes = 1)	(+)	1.1503	***	0.4324	***	0.02
Need for better quality light (Yes = 1)	(+)	1.9133	***	0.6102	***	0.02
Income (TK. per month)	(+)	0.0041	**	0.0014	*	6.34
Constant		-0.6396	***			
Number of Observations		2905				
Psuedo R-square		0.3273				
Log Likelihood		-1311.5636				
LR $chi^2(11)$		1277.98	***			

Note: † Index = Wall + Floor + Roof is a composite index where wall/roof/floor is 1 when materials used for wall or floor or roof are brick/tally/tin and 0 otherwise. †† measured as a categorical variable 0 for farm size between 0 and 50 decimals, 1 for 50 and 100 decimals, 2 for 100 and 250 decimals, 3 for 250 and 500 decimals, 4 for 500 and 750 decimals and 5 otherwise. Sig. is * when coefficient or marginal effects is significant at 10% (in a one-tail test), ** means significant at 5% and *** means significant at 1% level (all for one tail test for the expected signs of the coefficient).

Source: Estimated BIDS survey 2012.

7.3 Willingness to Pay for SHS Unit

The WTP concept generally refers to the economic value of a good to a person (or a household) under given conditions. Net economic benefits of SHS electricity services are, therefore, estimated as the difference between the consumers' maximum WTP for a SHS

[16] Note that the earlier chapter on impact also had a probit model which is different in that its purpose was not to estimate demand but to have proper matching for the PSM. Here we are trying to find also some kind of idea as to what type of SHS does a client purchase and is based on the CV method.

unit and the actual cost of the services. Table 7.2 shows that at the mean of the sample, WTP is Tk. 24,028[17] for a SHS while the average price is Tk. 18,283. This means that on average a household extract about Tk. 5,744 as consumer's surplus (see Figure 7.1 below). However, estimates also show that net benefit to the households is the highest when they purchase a SHS with Wp 20 (analyses in chapters 4 and 6 also show that households are now opting increasingly for the 20 Wp packages). At the same time, our estimates show that while average willingness to purchase is 32% (of the households) in a rural area, 62% of the demand is for Wp 20, 14% for Wp 40, 12 % for Wp 50 and 11% for Wp 65 or above.

Figure 7.1: Measurement of WTP and Consumer's Surplus

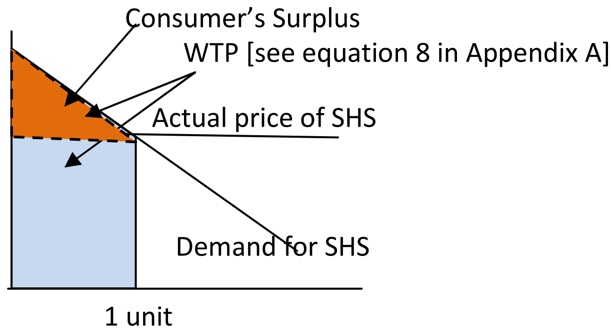


Table 7.2: WTP for SHS in Off-grid Areas of Bangladesh

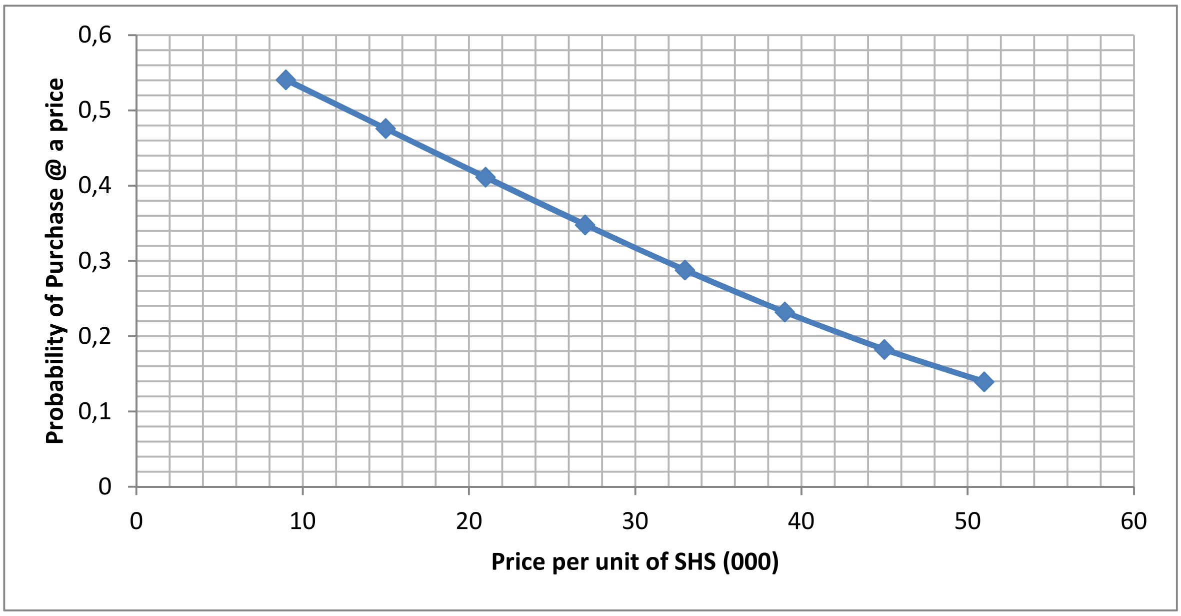
Size of SHS	WTP	Actual price paid by households for purchasing SHS	Consumer's surplus	Probability of purchase
At sample mean	**24,028.64**	**18,283.84**	**5,744.80**	**32%**
for Wp20	37,691.30	12,560.70	25,130.60	62%
for Wp40	42,838.81	22,885.24	19,953.57	14%
for Wp50	50,098.05	28,157.52	21,940.53	12%
For Wp65	57,569.55	33,609.69	23,959.86	11%

Source: Estimate based on BIDS survey 2012.

The probit model is also used to find the probability of purchasing the SHS at different prices. Figure 7.2. shows that as price of SHS goes up the probability of purchase will decrease. Based on this, it is possible to calculate the elasticities of demand for SHS for different prices.

17 The theoretical foundation is given in the Appendix A.

Figure 7.2: Probability of Purchase of SHS at Different Prices



Source: Estimate based on BIDS survey 2012.

7.4 Elasticity of Demand and Implications

7.4.1 Elasticity of Demand for SHS

Probit estimates of the demand for SHS can also be used to estimate the elasticity of demand for SHS. Estimates show that on average price elasticity of demand for SHS is 0.85 or it is inelastic. This means that POs selling SHS unit will have a tendency to raise price if there is an opportunity. Under this condition, IDCOL should ensure that market competition exists and allows new POs to enter into the market regularly.

Table 7.3: Estimates of Elasticity of Demand for SHS

With respect to	Elasticity at the sample mean values
Price of SHS	-0.85
Housing Quality Index †	0.37
Number of Students in the Household	0.22
Farm Size ††	0.37
Income	0.03
Price Elasticity at Different Prices (at mean of the sample) – price is in Tk. ‘000	
Mean Price of the SHS	Price Elasticity

9.00	-0.42
15.00	-0.70
21.00	-0.98
21.51	-1.00
33.00	-1.53
39.00	-1.81
45.00	-2.09
51.00	-2.37

Source: Based on BIDS survey 2012.

7.4.2 Wealth and Income Effect on Demand for SHS

Income and wealth elasticities of demand for SHS were also estimated from the probit results. Table 7.3 shows that wealth effect on demand is the highest 0.37 for wealth measured in farm size or in terms of housing structure index. On the other hand, income effect is the least at 0.03. Accordingly, it is evident that increase in demand for SHS is driven more by wealth than by income.

7.4.3 Education Need Impact on Demand for SHS

The estimated elasticity of demand for education is 0.22. Educational need is measured using number of school going children in the household. This means that households do use and are ready to pay for SHS to ensure that their school going children gets the benefit of better lights for studying at home.

Therefore, it is concluded that demand for SHS is affected by a) prices of the SHS units, b) wealth status of the households (wealthier households have more demand for SHS), c) need for education in the households (measured through the number of school going children).

7.4.4 Net Surplus Generated in the Economy from SHS

The average consumer's surplus for SHS was estimated at Tk. 5,744.8 per unit. Insofar the total SHS sold is about 2 million, the sales of SHS has generated net benefits of Tk. 11,490 millions. All these benefits accrued to the households using SHS systems in off-grid areas.

7.5 THE SIZE OF THE SHS MARKET

7.5.1 Market Size

According to the Census 2011, total number of households in Bangladesh is around 25.5 millions. Nearly 48.8% of the rural households are connected to the grid electricity and another 4% of the households are using the SHSs (Census 2011). Given this backdrop, the study used the demand function estimated using CV method (Table 6.1, above) to estimate the market size for SHSs for different prices and for different packages.

Table 7.4 shows the estimated market size for different SHS systems. These demand estimates are mutually exclusive in the sense that the demand is estimated if only one of the packages are made available at different prices.

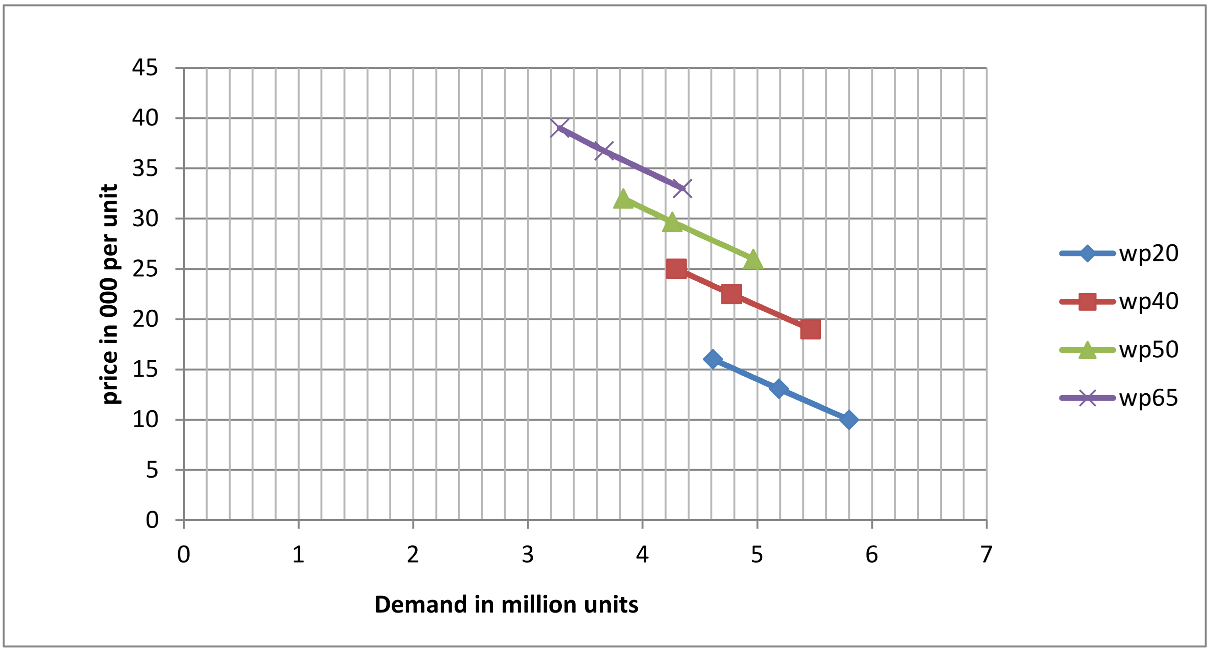
Table 7.4: Market Size for SHSs (Beyond the Current Status)

Price	SHS Demand (in Millions)			
In Tk. '000	Wp 20	Wp 40	Wp 50	Wp 65
10.00	5.80			
13.07 *	5.19			
16.00	4.61			
19.00		5.47		
22.49 *		4.78		
25.00		4.30		
26.00			4.97	
29.68 *			4.26	
32.00			3.83	
33.00				4.35
36.73 *				3.67
39.00				3.28

NOTE: * indicates the average prices from the sample.

Table 7.4 indicates that Wp 20 SHSs (which is the most popular in terms of units sold), have a demand for 5.2 million units at the current market price. This is outside the number of units sold until now. Nearly 1.1 million SHS units were sold (at the time of the survey), therefore, the market size is nearly five times the existing number of units sold in rural Bangladesh. However, if Wp 40 SHSs are provided in the market the demand will fall to 4.8 million (about 0.4 million less) and this is due to both price rise and the need of the household. The number drops to 4.3 million for Wp 50 and to 3.7 for Wp 65 packages. These are shown also in Fig. 7.3.

Figure 7.3: Demand Curve for SHSs



Total market size for SHS systems could be apparently thought of adding the market for each product and it is between 16 to 20 million. However, this cannot be true since a household having purchased a Wp 20 unit is unlikely to purchase a Wp 40 unit because of the fact that Wp 40 is a close substitute for Wp 20 but costlier. Thus, such addition across capacity may grossly over-estimate the market size for SHS units. Therefore, using the current proportion of market shares for each products, the probable market size for SHS units will be between 4 million to 5.12 million SHS units.

Results of the probit analysis further shows that the wealth impact on demand is much higher than income effect. This means, rise in current income is not likely to increase demand but if households have savings so that they can improve their standard of living through improving housing walls or roofs, and other assets, the demand for SHS will increase. This has, therefore, long term implications. Finally, it is likely that demand for SHS will fall if the coverage of the REB increases to current off-grid areas.

7.5.2 Elasticities of Market Demand

The demand curve estimated above (Table 7.1) is for individual consumers. Based on the market size estimates in Table 7.4, elasticities of demand for each type of SHS can be estimated at the mean. It shows that elasticity of demand for Wp 20 (at mean price) is -8.6, implying that a 1% fall in price will increase demand for Wp 20 SHSs by 8.6%. Similarly elasticity of demand for Wp 40 SHSs -17.6, and it is -37.2 for Wp 50 and -41.4 for Wp 65 SHSs. It shows the sensitivity of demand for SHSs if price changes. This has implications on withdrawal of subsidies on the products too.

7.6 Impact of Financing Mechanisms on Welfare of Households

7.6.1 The Simulations

In order to promote SHS units in the off-grid areas, IDCOL currently follows a strategy of incentives for the POs as follows: (i) lump sum grant at US$ 25 per unit of SHS sold (at the time of the survey); (ii) at least 10% of the price (after deducting the grant) is paid by households as down payment; (iii) The rest is repaid by households in monthly installments for a 3-year period at 12% rate of interest.

In order to understand possible impact of changes in these parameters on the households, a computer simulation model was developed. The model used a 'what if' analysis in order to understand the impact of changes. This means given a reference case, the model shows the impact on price of SHS system, interest rate charged to households, and total repayment by the household. The model assumed that POs will maintain the same rate of return with changes in the interventions by the donors through IDCOL.

The reference case for simulation model is developed for an average price of Tk. 18,283 paid currently by the households (at mean of the sample), for which the actual price of the SHS system is Tk. 18,283 + US$ 25 = Tk. 20,312[18]. Based on this price, households pay 10% as down payment in order to install the unit at home. The rest is taken as a loan at a simple interest rate of 12 percent for three years. As a result, at the end of the 3rd year, total payment from the household (including interest paid) is Tk. 24,207 per unit.

7.6.2 Impact of Withdrawal of Grants

Figure 7.4 shows the results of this simulated exercise under different scenarios to see the impact of changes in the incentives on the total payment made by a household, on resources of the POs and on prices of the SHS unit. It shows that withdrawal of grant of US$ 25 per unit will increase prices of the SHS unit. As a consequent of this withdrawal of grant for a unit of SHS, final payment by the household will go up by Tk. 2,686. However, it also shows that households now have to pay higher amount as down payment, IDCOL has to allocate more resources (part of its 80% commitment, see above) and that POs also need to allocate more resources to finance SHS units for each household. Consequently, the rate of return on capital invested by POs will go down if the interest rate or the time period remains same.

Figure 7.4: Impact of Changes in the Financial Incentives on Households

18 1 US$ = ৳81.12 (Bangladesh Taka)

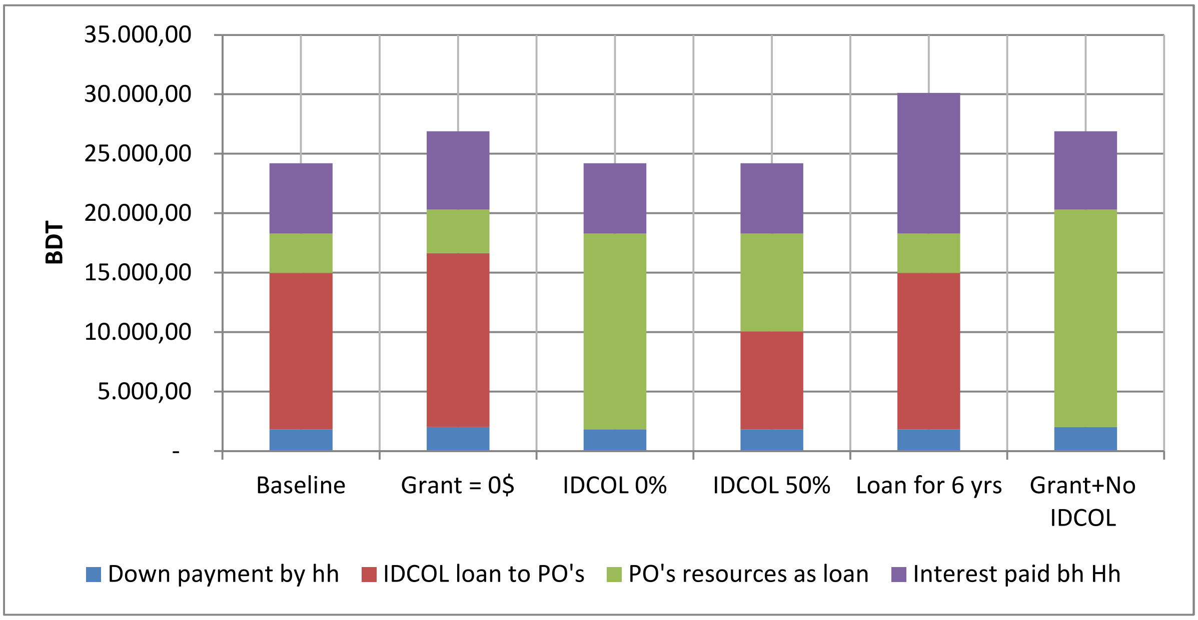


Table 7.5: Impact of Withdrawal of Grants

Grant amount in US$	Average take home price for household	Average cost price for a Household	Rate of return in 3 years	Interest paid by household	Subsidy reduce by (in Tk.)	Burden on the household in terms of total payment	Burden per taka of subsidy withdrawn
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(7/6)
25.00	18,283.84	24,207.80	36.00%	5,923.96	-	-	
20.00	18,689.59	24,207.80	36.00%	6,055.43	405.75	537.21	1.324
10.00	19,501.09	24,207.80	36.00%	6,318.35	1,217.25	1,611.64	1.324
-	20,312.59	24,207.80	36.00%	6,581.28	2,028.75	2,686.07	1.324

Source: Simulation results by the authors

Table 7.5 shows impact of gradual withdrawal of grant on household. It shows that if the grant is reduced from US$ 25 to US$ 20 for example, the take home price will go up to Tk. 18,689 (increase is equivalent to the amount of grant), however, households will now take a higher amount of loan and so total payment goes up by 32% more at the end of the loan period.

7.6.3 Impact of Reducing Loan to POs by IDCOL

Figure 7.4 further shows the total impact on the payment if IDCOL changes its current commitment of 80% re-financing to 0% and to 50% respectively. It shows that there will be no impact on the total payment made by the households due to such withdrawal. However, there are two consequences. *First*, POs now need to find more resources to ensure that sufficient fund is available to them to finance loans to the household. This will cause additional burden on their resources. *Second*, there will be a reduction in the rate of return to the POs.

Given these two impacts, it can be argued that additional burden on the resources of the POs will sway them to sell the units either on cash on delivery basis. Smaller POs will even be unable to continue to support this at the rural level. At the same time, since the rate of return will fall (from 36% to 12% as re-financing drops from 80% to 0%, see Table 7.6), POs are likely to increase the rate of interest to compensate for the loss of return. Table 7.6 further shows that interest rate will increase 3% for every 10% drop in IDCOL's share of re-financing. As such, at 0% re-financing by IDCOL, interest rate to be charged by POs to households will rise from 12 (at present level of IDCOL support) to 36% if they decide to retain the same rate of return to their investments.

Table 7.6: Impact of Changes in IDCOL's Share of Re-financing POs

IDCOL's share in financing	Take home price of SHS for household	Actual cost price of SHS units	Rate of return of PO's in 3 years	Interest paid by the HH in 3 years	Expected interest rate for HH*
80%	18,283.84	24,207.80	36.00%	5,923.96	12%
60%	18,283.84	24,207.80	21.00%	5,923.96	18%
40%	18,283.84	24,207.80	16.00%	5,923.96	24%
20%	18,283.84	24,207.80	13.50%	5,923.96	30%
10%	18,283.84	24,207.80	12.67%	5,923.96	33%
0%	18,283.84	24,207.80	12.00%	5,923.96	36%

Source: Simulation results by consultant

Note * at this rate of interest PO's will have same rate of return as in the reference case in the model

7.6.4 Impact of Changes in the Duration of Loan to the Households

At the moment, POs approve a loan for 3 years to the households purchasing a SHS unit. Average payment for such unit (take home price) is Tk. 18,283. However, IDCOL provides the loan to POs for a period of 6 years. This means, while households repay the amount gradually, POs probably re-circulate this money in loans to others and so for each loan given to a household, POs use the fund for two such loans and retain additional interest income. As a consequence, a natural question arises: if IDCOL asks the POs to also extend loan period from 3 to 6 years period, will it have any impact?

To answer this question, we have simulated the model with changes in the loan period. Table 7.7 (and also Figure 7.4) shows that with no changes in the rate of interest of 12% this will mean increase in the total payment by the household. As such, payment after the end of the loan period made by the household will be around Tk. 30,131 instead of Tk. 24,207 if the loan period extends to 6 years. If, however, IDCOL regulates the interest rate for the households, then the corresponding interest rate will be 9% for a 4 year period, 7.2% for a 5 year period and 6% for a 6 year period. However, it will also mean significant loss in the rate of return at the PO level. Consequently, the market will see reduced competition and probably an increase in prices.

Table 7.7: Impact of Changes in the Loan Period to Households

Loan period in years	Actual Take price of SHS	Total payment by the Households	Rate of return	Interest paid by HH during the period	Matching interest rate for same interest earning by PO's
3.00	18,283.84	24,207.80	36.00%	5,923.96	12%
4.00	18,283.84	26,182.46	36.00%	7,898.62	9.00%
5.00	18,283.84	28,157.11	36.00%	9,873.27	7.20%
6.00	18,283.84	30,131.77	36.00%	11,847.93	6.00%

Source: Simulation results by consultant

7.6.5 Impact of Changing the Rate of Interest

Under its current re-financing scheme, IDCOL provides 80% of the fund to POs to support the credit facilities to the SHS unit buyer. For this financing arrangement IDCOL charges 6% interest rate for period of 6 years. POs, on the other hand, charges 12% interest for a period of 3 years to their customers. As such it has been argued IDCOL might look into the possibility of regulating the interest rate charged by POs. Table 7.8 shows the simulated results.

It shows that as interest rate charged by POs will be reduced, the rate of return will also fall. For example at 12% rate of interest, average rate of return is 36% for 3 years, it will go down to 26% if the interest is regulated at 10%. On the other hand, it is possible for POs to demand a corresponding fall in the interest rate charged by IDCOL. Table 7.8 shows that for each percent drop in interest rate charged to households, POs would expect a 1.2% drop in the IDCOL's rate of interest to maintain the equity in terms of rate of return.

Table 7.8: Impact of Regulating the Rate of Interest

Interest rate by POs	Take home price of SHS unit	Cost price of SHS unit	Rate of return in 3 years time	Interest paid by household to POs	Would be interest rate by IDCOL
12.0%	18,283.84	24,207.80	36.00%	5,923.96	6.00%
11.0%	18,283.84	23,714.14	31.00%	5,430.30	4.8%
10.0%	18,283.84	23,220.48	26.00%	4,936.64	3.5%
8.0%	18,283.84	22,233.15	16.00%	3,949.31	1.0%

Source: Simulation results by the authors

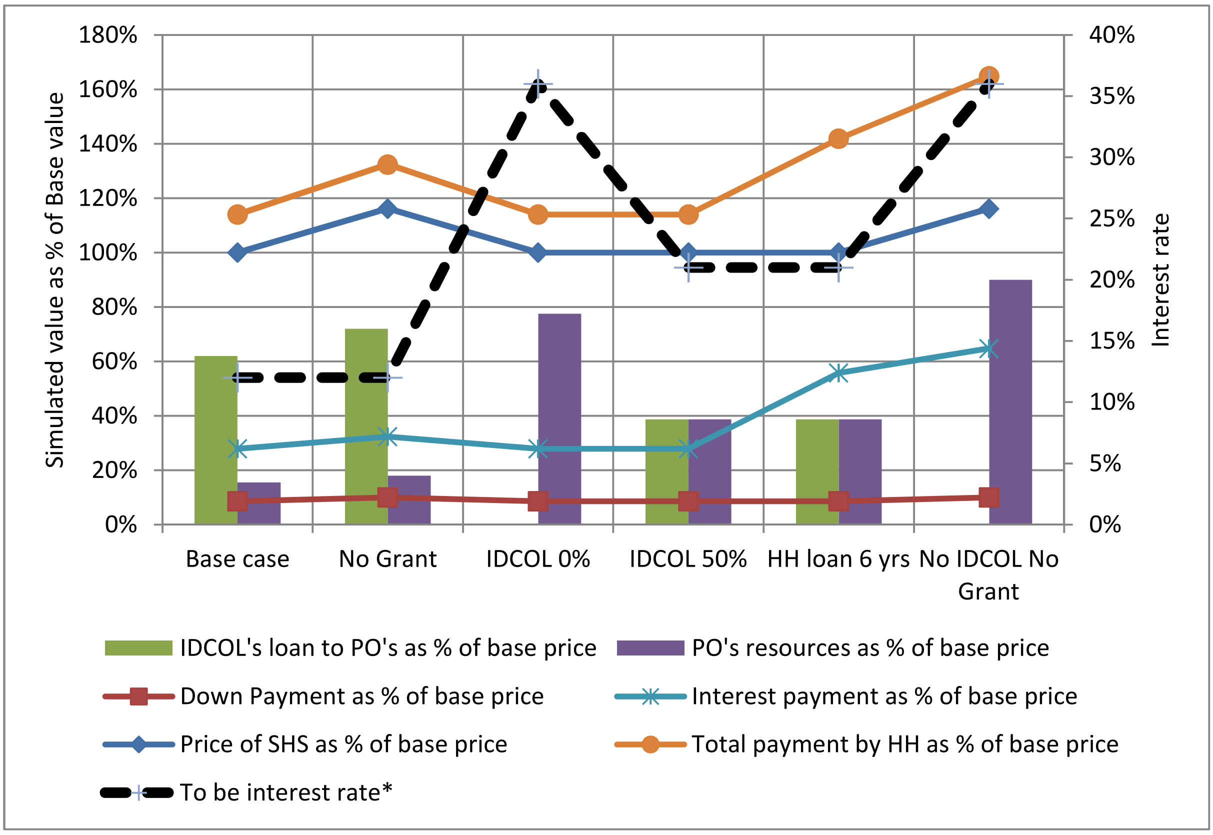
7.6.6 Impact of Withdrawing All Incentives

Finally, if it is assumed that all incentives by IDCOL will be withdrawn from SHS selling in Bangladesh, the take home price will surely rise but the biggest impact will be in terms of total price paid by the households to the POs. Figure 7.4 shows that SHS unit price with interest will rise to nearly Tk. 26,893 from its current level of Tk. 24,207. This is same as withdrawal of grants. However, the rate of return will drop to only 12% in 3 years which is unsustainable. Alternatively, it is possible to increase the loan period to 6 years. Analysis shows, that the price after repayment of loan will increase to Tk. 33,475 but there will be no increase in the rate of return. Therefore, it can be argued that withdrawal of incentives will increase the rate of interest from 12% to a minimum of 36% in order to maintain their current rate of return.

Figure 7.5 summarizes the results of the simulation for Wp20 SHS unit. It shows, that by changing the role of IDCOL, there will be impact on both prices paid by household and on interest. However, the impacts are not same. For example, when grant elements are withdrawn, price will rise by 16%, POs will retain their normal rate of return and there will be no expected impact on the rate of interest charged by POs to the households.

On the other hand, if IDCOL's provision of loan (to POs) is withdrawn there will be no impact on price but this will mean greater resources from the POs to finance the purchase and hence with same rate of interest, there will sharp fall in rate of return to investment. Simulation results show that the interest rate will have to increase to 36% in order to compensate for this. Similarly, if IDCOL decides to extend the years of loan provision for the household, the impact is even worse. It will have both impact on the interest rate and the final payment by the household with no impact on the take home price of SHS.

Figure 7.5: Impact of Changes in IDCOL's Role on Prices and Interest Rate



Source: Simulated results under different scenarios.

Finally, for a Wp 20 SHS unit, if the both grant and IDCOL’s re-financing provision are withdrawn, the expected impact will be both on price and interest rate. Interest will rise to as high as 36% (from 12% at present). However, for the give interest rate, the price (take home) will increase by 16% and final payment will increase by 65%. The rate of return will drop and to compensate the final impact will be on interest rate.

Annex to Chapter 7: Measurement of Willingness to Pay[19]

The study used a closed-ended dichotomous choice elicitation method in order to estimate the WTP. Theory behind the estimation of mean WTP is explained here. Assume that the household's utility depends on a composite commodity X and leftover money (Y) available for paying for a SHS. Utility has a deterministic component (first and second terms of the right hand side of the equation (1)) and a stochastic component, ε. Utility of the household before answering the CV question is:

$$u_0 = X_0\beta + \gamma Y + \varepsilon_0 \tag{1}$$

Utility of the household can be given by equation (2) if the household answered yes to the CV question, where WTP is the maximum amount of money the household is willing to give up to purchase a SHS.

$$u_1 = X_1\beta + \gamma\,(Y - WTP) + \varepsilon_1 \tag{2}$$

By subtracting (2) from (1),

$$u_0 - u_1 = (X_0 - X_1)\beta + \gamma WTP + \varepsilon_0 - \varepsilon_1 \tag{3}$$

By replacing (X_0-X_1) as X,

$$u_0 - u_1 = X\beta + \gamma WTP + \varepsilon_0 - \varepsilon_1 \tag{4}$$

By taking expectation on both sides

$$E[u_0 - u_1] = E[X] \bullet E[\beta] + E[\gamma] \bullet E[WTP] + E[\varepsilon_0 - \varepsilon_1] \tag{5}$$

Since E(β)=β and E(γ) = γ, the simplification results

$$E[u_0 - u_1] = E[X] \bullet \beta + \gamma \bullet E[WTP] + E[\varepsilon_0 - \varepsilon_1] \tag{6}$$

In answering the questions on CV, the households responds by maintaining the same level of utility while giving up the amount of money equal to WTP (the bid offer), and acquires the improved services. Thus,

$$0 = E[X] \bullet \beta + \gamma \bullet E[WTP] \tag{7}$$

Therefore, Mean WTP for the sample is:

$$E[WTP] = -\,(E[X] \bullet \beta) / (\gamma) \tag{8}$$

Equation (8) provides the estimates for Mean WTP for the sample in the study.

[19] Derived from (Gunatilake, Yang, Pattanayak, & Berg, 2006)

CHAPTER 8

TECHNICAL QUALITY OF THE SHS AND BACKSTOPPING SERVICES

8.1 Introduction

The SHS units, especially the PV modules that the POs offer to clients, are approved by the technical committee of IDCOL to ensure quality. Concomitantly, the POs through their field offices, promise after-sales services for a certain period of time. Even after normal warranty period, the POs claim to provide services through extended warranty. It is also true that a minimum level of education-cum awareness on the part of the clients is required to operate the SHS. However, such precautionary measures may not be taken by the clients while operating the system. It is, thus, necessary to evaluate the technical quality of the systems, the nature of problems experienced by the clients, the major causes of behind these problems and the level, frequency and quality of backstopping services provided by the POs.

Owing to size and complexities of the SHS it may take the representative(s) of the concerned POs from a few minutes to well about 5 hours to explain/demonstrate the operational aspects of the system to the clients. Clients of the SHS are generally supplied with loads that include black and white TV, lights, mobile charger etc. While installing the SHS, the most commonly faced problem includes inappropriate condition of the rooftop, which may be dangerous or improper for installation of the system. During the usage period the most commonly faced problems (faced by the customers) include malfunction of the inverter or charge controller owing to the damage of the battery due to regular deep discharge. Although most of the SHS loads are DC, locally made square wave inverters are available in the market if the customers wished to power AC loads with their system. However, it has been reported that the inverters supplied by most of the POs has an efficiency of 50%. The locally made charge controllers (usually PWM or relay controlled) available in the market are compatible with most of the SHSs. Hardly any backstopping service is given on the benefits of tilting the PV module in summer and winter to extract maximum power from the module during these seasons.

As have been indicated earlier, surveys were conducted among both PO field offices and the households. Some of the questions put to them pertain to the efficacy and reliability of the SHS units installed, backstopping services, their quality and customer satisfaction. A few of these issues had been touched upon cursorily so far. Here we try to provide more of the details.

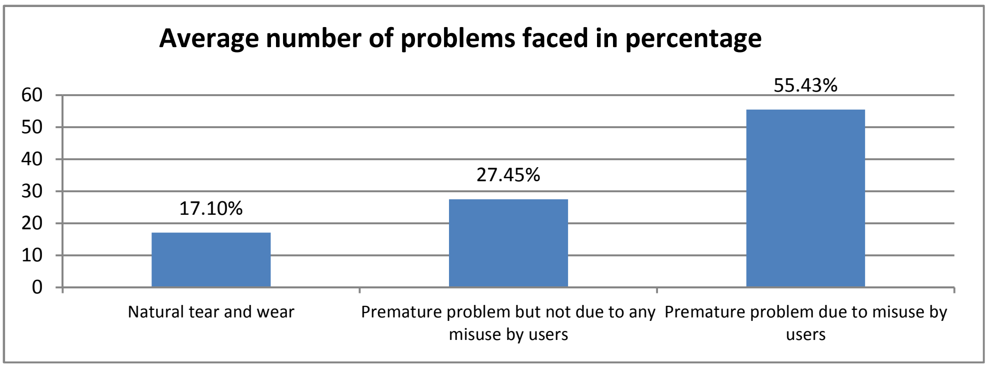
8.2 PO Level Analysis

8.2.1 Major Causes of Damages

The survey on the PO field offices reveals that natural wear and tear causes problems in about 17.1% of the SHSs supplied by the POs, premature problem other than misuse by the clients causes in another 27.4%, and sheer misuse by the clients causes premature problems in the rest 55.4% of the system. The last type of problems can be reduced by intensification of the existing training program on the basic operations of the SHS to households.

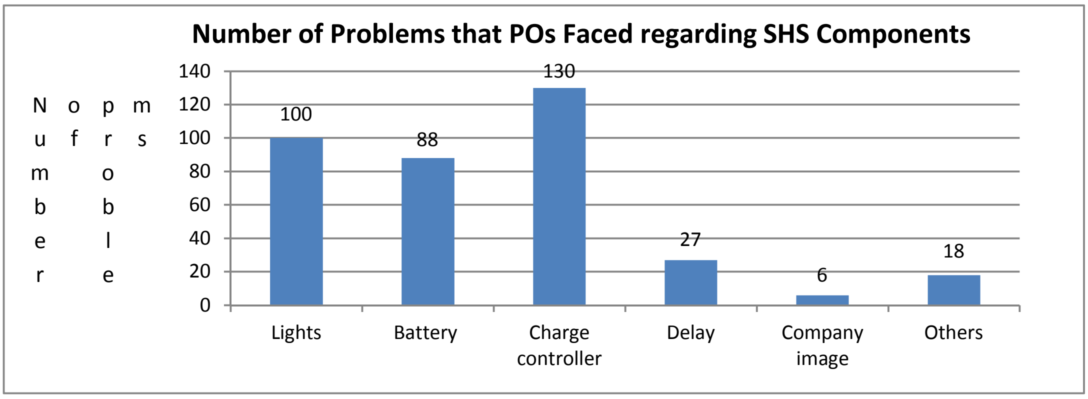
About 74.1% of the POs reported to have problems regarding inferior quality of lights/CFL bulbs, 96.3% of the POs reported to have problems regarding inferior quality of charge controller, 69.2% POs have problems regarding inferior quality of battery, 37.8% of POs face problems related to company image, delay of orders, etc.

Figure 8.1: Major Causes of Damage to the SHS during Last 12 Months



Our survey results reveal that POs face problems due to inferior quality of lights and charge controllers. In contrast, batteries seem to pose less of a problem. The quality of the lamps and the charge controller the POs usually manufacture or import is usually low. Due to the enormous growth of SHS in recent years, POs have to supply a large number of components regularly. Thus, lack of institutional capacity and required human skill for management of technical installations due to monumental growth of the SHS could be one of the major reasons behind the fall in the quality of components supplied.

Figure 8.2: Problems Reported to the POs during Last 12 Months



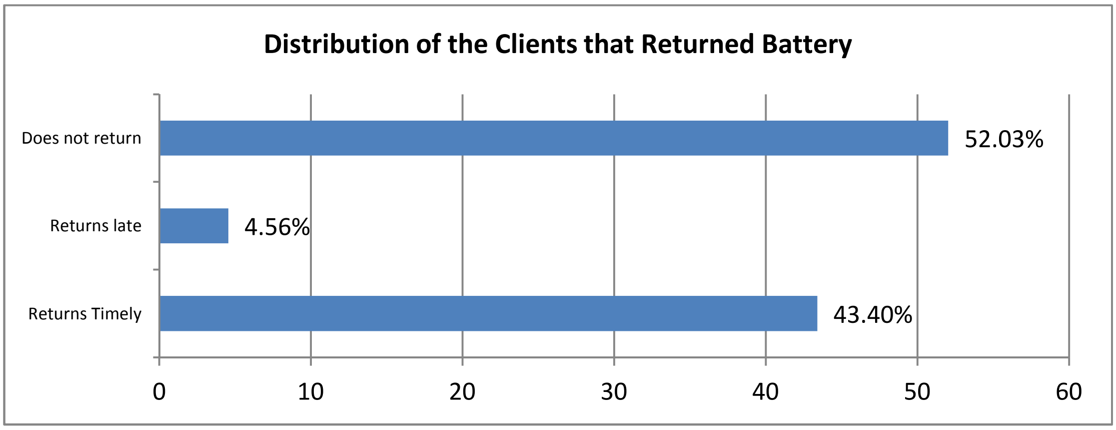
8.2.2 Management of Components

It may be noted that battery and charge controller has specific warranty period and managing damaged components, especially battery, may create environmental hazards. The POs have their own program to create awareness among the buyers about the safe disposal mechanisms of the damaged components. Our findings reveal that nearly 43% clients return battery whenever it is damaged; about 4.6% usually return it after the warranty period. However, more than 50% of the clients do not return at all. The latter group either disposes them off in unsafe manners or recycles them for activities that are hazardous both to the workers and the environment because of the carbon emission and other related chemical problems. Improper disposal of lead acid batteries can lead to acid leakage to soil and water bodies that can severely deviate from the required pH of soil for cultivation of crops as well as kill fishes and cause skin damage to those whole take bath in those contaminated water bodies. Fumes that may come off the acid, causes severe eye irritation and breathing problems.

Acute lead poisoning can occur when people are directly exposed to large amount of lead through inhaling dust, fumes or vapors dispersed in the air. However, chronic poisoning from absorbing low amount of lead over long periods of time is a much more common and pervasive problem. Lead can enter the body through the lungs or the mouth, and over a long period can accumulate in the bones of human body. Health risks include impaired physical growth, kidney damage, retardation, and in extreme cases even death. Lead poisoning can lead to tiredness, headache, aching bones and muscles, forgetfulness, loss of appetite and sleep disturbance.

It may be noted that proper recycling of batteries can bring down the cost of replacement battery. Improper disposals of batteries are a cause of concern because the number of people who do not return the battery may sharply increase with the galloping growth in the adoption of the SHS in future. IDCOL reported that it has recently introduced several strengthening measures to ensure proper disposal of batteries. The measures include making all the battery manufacturers and recyclers compliant with ISO 14001:2004 and OHSAS 18001:2007 compliant; increasing incentives for households to return the expired batteries to the POs and not to backyard smelters; and providing incentives to the POs to return the expired batteries to the approved recycling centers. All these incentives were introduced after our survey was conducted, as such testing the effectiveness of the strengthening measures was beyond the scope of this study.

Figure 8.3: Management of Damaged Batteries



8.3 Household Level Analysis

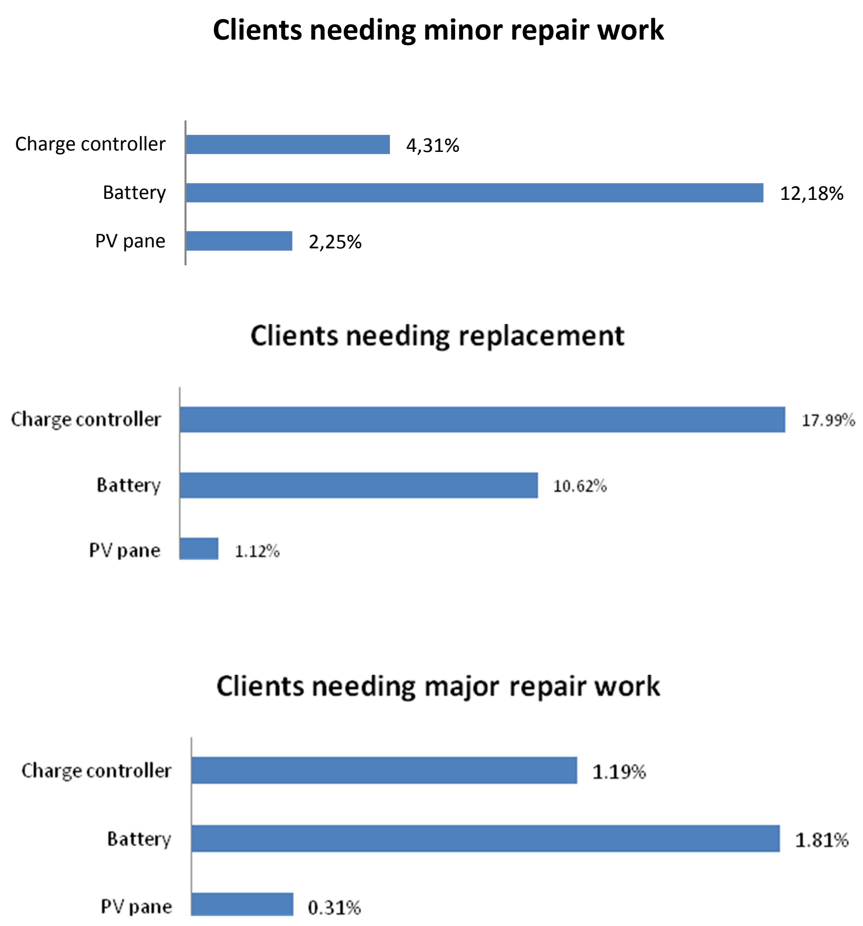
Earlier it has been shown that the number of connections that the SHS households have vary from 2 to 5, on average somewhat around 3 connection points for light, one in every two clients runs TV and every client charges their cell phones. Number of hours that all the loads are run through SHS varies from 1 to 9 hours, with an average of 3.69 hours per SHS.

Of the 1600 clients, only 18 have reported problem regarding the PV panels that required replacement, 5 have reported the need of major repair works and 36 reported need of minor repair work. Thus, a vast majority of the clients hitherto have not required any necessity of repair works or replacement of the PV module. In contrast, 170 or 10.7% of clients required replacement of their batteries, 29 (2%) required major repair works and, 195 (12%) clients needed to call their POs for minor repair works (Fig. 8.4).

For the charge controllers, 14.2% of the clients have had their charge controllers replaced due to damage/breakdowns whereas, only 1.1% of the total clients reported the need for major repair works and 4.3% clients have had minor repair works done on their charge controllers.

Earlier we indicated that batteries and charge controllers may need replacement even before the expiry of warranty period. The timing of replacement of batteries and charge controllers were not investigated in case of households. Instead, users were asked whether actual replacement was required. Corresponding to the timing of installation of SHS a broad picture, however, emerges regarding “premature” replacement. Thus, for batteries, the proportion of households needing replacement was 10.1% for SHS installed during the last five years. For those who installed more than 5 years ago, the proportion was 19.6%. But this latter figure is difficult to interpret and cannot be directly compared to the more recent installations for premature replacement. Similarly for charge controllers, replacements should not generally occur within 3 years of installation. But we found that households needed replacements in 11.4% cases of recent (i.e., installed within last three years prior to survey) installations and 24.5% in case of those installed more than 3 years before. These figures do indicate that some of the batteries and charge controllers have either been of low quality or that their operations were not proper.

Figure 8.4: Problems Faced by the Clients since Installation



The survey results also showed that over-all 52% of the total clients had to change their tube lights in contrast to only 14% for the CFLs during the 12 months prior to the survey. On the whole, 13.5% clients had changed their tube lights and 8% have changed the

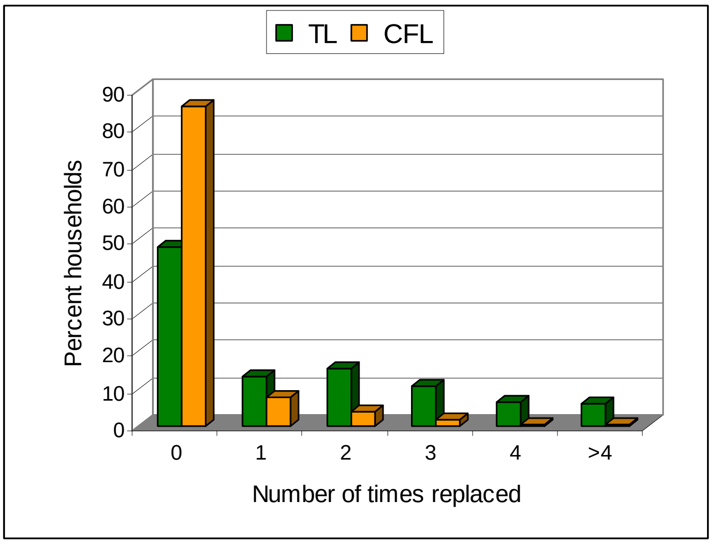
CFL only once during the 12 months preceding the survey. Corresponding figures for two changes a year were 15.4% for tube lights and only 4.% for CFLs. Similarly 10.6% clients have changed their tube lights and 1.6% have changed their CFLs thrice, 6.6% clients changed tube lights four times but only 0.44% clients changed their CFLs and 2.6% clients had to change their tube lights more than five times last year whereas only 0.2% changed CFLs more than 5 times. We thus find that the problem of changes of lamps was basically for those who used tube lights rather than CFLs. Whether these replacements were within the warranty periods could not be ascertained, but apparently this probably had been an issue, if at all, for linear fluorescent lamps. A further difficulty in assessing this situation was due to the fact that the questions were not separately asked particularly for tube lights if the lamp itself had to be changed or the fixtures.

Another difficulty is that there are all types of lamps in the market of varying durability. Exactly what lamp of what warranty was purchased by the SHS users and at what time is difficult to get information on and assess for technical management. Thus perhaps changing lamps once or twice in a year may be taken to be normal but beyond that this needs to be probed rigorously. As we have shown above, for linear tube lights, almost 11% changed them 3 times a year. That may be too many. Yet, again here we have the difficulty of understanding if it is the same connection point for which the lamps were changed or every time a different one?

The number of times the clients had to change their lamps was not high particularly for CFLs. But note that in many cases the SHS had been in operation only for a short period of of 2-3 years. In any case. alhough the pattern shows high reliability, particularly of CFLs, the replacements being done without proper knowledge of the system could lead to damages (to lamps as well as fixtures) as a client unaware of technical compatibility issue might purchase lamps that do not fit well with their system. Using a lamp that might draw more power than the lamp sold with the package could deepen discharge of batteries reducing longevity and eventually damaging them.

Drawing higher power than the system is designed for may lead to higher discharge than recoverable by the panel. The charge controller only disconnects the battery when it is at its LVD point, however it does not provide any protection (e.g. trip circuit, current limiting circuit or logic control) against power consumption higher than accounted for in the system design. Full charging of the battery to its nominal capacity may take longer than usual, resulting inconvenience to users. On the whole, the information here are not precise enough for taking action although there is a general case for IDCOL taking some steps like setting and enforcing regulations in this regard.

Figure 8.5: Change of Tubelights (TL) and CFL during Last 12 Months



8.4 Were Installations Done Properly?

We have not probed this issue as time and resources did not permit field visits to a large sub-sample of the installations. However, other technical exercises were on-going at the time of the present study. It would be instructive to refer to the findings therein (KFW: no date) as these more or less point to the similar conclusions of need for gearing up technical quality of the installed SHS.

The KFW report had examined the technical quality of installations and quoted the results of successive periodic monitoring. These findings show that installations were either deficient or needed attention in 63% cases (4% installation deficiency) during July 07-August 08. During November 09-February 11, the figure has shot up to 79% (with 7% deficient installations) and then fallen to 62% (7% deficient installation). These figures very clearly indicate that the POs need to gear up their technical management capability and employ skilled work force. We believe that the various problems that we have discussed above and the increasing trend towards accumulation of problems and installation quality are intertwined.

8.5 Assessment

The major merit of a SHS is that its purpose is to generate electricity from an abundant, free and clean energy source. The annual amount of radiation varies from 1840-1575 KWh/m^2, which is 50%-100% higher than that in Europe. Utilization of 0.07% of the radiation could meet the country's present electricity requirement. Silent electricity generation of a SHS means there is no noise pollution alongside any pollution like fossil based electricity generation.

On the other hand, the SHS is a complex technology which means loss of efficiency if every component does not work in well synchronization (for details see Annex to this chapter). Thus, although a SHS runs on free and renewable energy, these systems are prone to sub-optimal use, incorrect installation and a poorly designed SHS can cost more in terms of price per unit of electricity. This can cause mainly due to improper sizing of the system and the components used are of inferior quality.

For example, the typical efficiency of a SHS lies with 10-12% considering panels of efficiency of over 15%. But poor quality panels that have efficiency of around 10-12% would bring the efficiency down to around 7-9%. Use of DC to DC converters facilitates higher transmission distance but at the cost of minimum 5% power loss. Poorer quality also means having to replace the components more frequently. Experiments carried out in controlled environment in the laboratories confirm that typical overall efficiency of a SHS lies with the range of 10% to 12% depending on the quality of the electrical devices used. Among all the devices, the PV panel is conclusively the least efficient followed by the battery and the load. The DC to DC converter is a step-up converter which is often used in a SHS for increasing the transmission voltage, to reduce the line loss of the system for longer transmission. The converter can contribute to the loss of efficiency of the whole system.

The technical complexities as well as analysis of survey data shows that the clients need more training on usage and maintenance of battery as this can pose the most harm to the environment and clients themselves in case of damage. Proper recycling, when the battery is dead, should be encouraged. A new system has just been introduced for monitoring of battery collection and disposal. Only time will tell if this is working as anticipated.

Focus has to be brought on designing charge controllers with better reliability. This could be a small approach towards an effective solution against low quality SHS components and the misuse of the system by the users. Both users as well as POs can play vital role by collaborating with each other through providing training and feedback.

Another important issue is the standard qualification testing of SHS components in the country. Due to numerous manufacturers (local and foreign), the resulting devices contain components that sizably vary in all parameters. As a result, the overall quality varies across manufacturers. This unstable quality is increasing with the increase number of SHS installation and thus the system inefficiency. Maintenance of a standard quality will increase the life cycle of SHS. Maintaining this qualification testing will result in less discarding of components and consequent tossing of less environmental wastage (Khan, Rahman, and Azad, 2012). IDCOL reported that such a testing facility is being established in the country with support from the World Bank.

Installation of SHS will relieve its users from frequent power outages due to natural calamities and frequent load shedding. Proper sizing of the SHS can reduce electricity consumption (the energy consumption of a solar light can be less than 50% of that of a traditional light for same amount of lumen) from national grid or even make a user completely independent of the grid. This will also reduce the huge investment cost of setting up power station and transmission and distribution networks that Bangladesh government can hardly afford. If contract is awarded to IPP (Independent Power Producer) they may not be interested to install power station in remote areas for economic reasons. Also pilferage of power (so called system loss) will also be a major factor for efficient operation of the power station. An important advantage with solar electricity is that it makes electricity available also in remote areas; there is no need to wait for the extension of the grid electricity to get good light, or run radio and TV.

The quality of the PV panels and other components imported from other countries is assured by the international standards followed by the respective authorities. PV panels, nowadays, are being assembled locally which are cheaper but the quality is yet to be ascertained. No international standard laboratory or equipments for PV module testing means no tests are being conducted to ensure quality of these modules. PV modules with poorer fill factor and efficiency are flooding into the market due to this reduced cost and lack of knowledge among buyers. Higher quality for the PV panels should be assured by the technical standard committee of the IDCOL through establishing proper (supposedly international) standards so as to push local assemblers to improve their products. The testing facility that is being established will certainly help in this regard.

Charge controllers (mostly manufactured locally), battery (mostly manufactured locally) and solar lamps like CFL and LED lamps (both imported and locally assembled) are tested in accordance with the technical standard committee of the IDCOL standards at different laboratories. In order to implementation of international standards (e.g. IEEE, ISO, CIE, IEC etc.), international standard laboratories should be encouraged by technical standard committee of the IDCOL for the purpose of quality control. Maintaining testing procedures and conditions as suggested by the international standards can bring about desirable changes of the SHS components and set the proper standards for quality control for the technical standard committee of the IDCOL. Moreover, standards should be established for components, like DC fan, DC to DC converters etc, which nowadays are becoming popular, in order to maintain a certain quality and quantity of the power being supplied.

SHS also offers the advantage of low voltage system, which adds significantly to the users' safety and the disadvantage of the existence of a battery, which has very high short-circuit power, contains sulphuric acid, and releases inflammable gases. Such disadvantages can be overcome through use of properly designed cage for batteries that would ensure proper ventilation and reduced exposure of the battery electrodes. Lack of thorough training on the battery management and improper use of it can reduce the battery life significantly.

A major source of the principal disadvantages of SHS is that all the responsibilities of maintenance of the system is vested with the users, thus requiring proper technical training to be served. Insufficient training to the users on the system could lead to improper usage of system reducing effective system capacity and life. Care should be taken by the technical standard committee of the IDCOL to ensure that the users receive adequate training, especially on battery usage, maintenance and recycling policies. As the system is highly dependent on weather, lack of adequate sun light in cloudy, rainy days could significantly reduce power generated by a SHS. Such problems can generally be overcome by considering a three-day-autonomy for the system. A further solution can be the implementation of a backup system that can supply adequate electricity when irradiance is below a predetermined level.

IDCOL can very easily negate all the demerits of a SHS through more active participation in this regard. The component qualification tests can be conducted in accordance with international standards (e.g. IEEE, ISO, CIE, IEC etc.) for all sorts of components used in the system. For system designing, a more subtle and detailed method (like consideration of system losses, temperature compensation for the battery and controller, supply of enough energy for proper equalization of battery voltage etc) should be adopted to take the maximum advantage of the system while leaving provisions for improvement through various load application, e.g. during day time no lights are used in the rural areas, so the SHS may be used to drive high power machines allowing some commercial activities.

Mass awareness program could be initiated among the rural people to make renewable energy especially SHS popular. Government machinery can work closely with the private sector in this regard. Special training programs should be organized by the technical standard committee for effective use of SHS. Subsidies can also be given for conducting researches on increasing overall system efficiency of SHS and individual components. Links among the authorities, industries and universities should be formed to ensure effective research and development projects on these concerns.

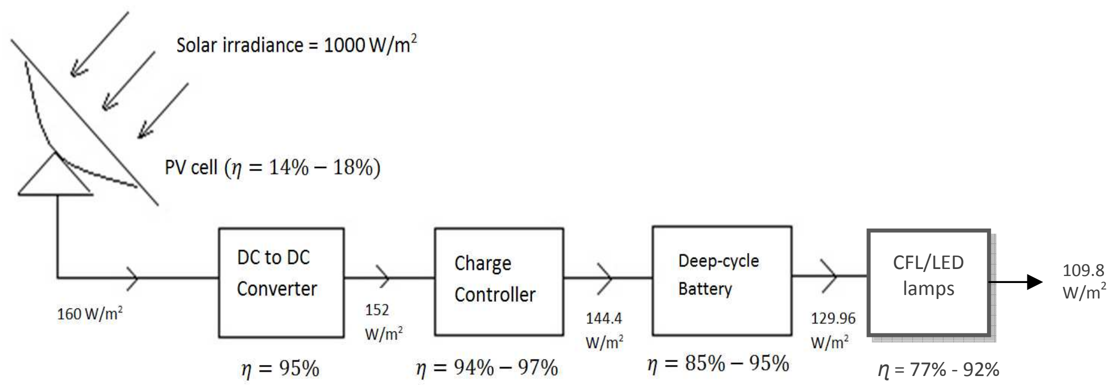
Annex to Chapter 8

Analysis of Technical Efficiency of an SHS

The analysis for the overall efficiency of a SHS is as follows

Schematically a SHS is what is shown in Fig. A.1.

Figure A.1 SHS Block Diagram Including the DC to DC Converter



The overall efficiency can be found by determining the product of the efficiency of the individual components.

Overall efficiency = G_{pv} X $G_{converter}$ X $G_{charge\ controller}$ X $G_{Battery}$ X G_{lamp}

= 0.16 X 0.95 X 0.955 X 0.9 X 0.845 = 0.1098

Output Power = Overall efficiency X Input Power = 0.1098 X 1000 W/m^2 = 109.80 W/m^2.

However, the efficiency of the overall system increases if the dc to dc converter can be removed from the system.

CHAPTER 9

Summary and Conclusions

9.1 The Study Objectives

The present study has two basic objectives, *first* to assess the impact of solar home systems on the household and *second* to find out the present institutional structure and financing mechanisms in reaching the solar homes to people keeping in mind that while households wish to have cheaper systems, they also want quality services and that those reaching the services to them also can have a reasonable market based profit to remain in business now and in the future. To this effect, this study has attempted to assess the household level impacts of the SHS in the country based on a nationally representative household survey with proper geographical focus. Two more surveys, one on community and the other on the field offices of POs have been conducted.

9.2 The Issues

Given that the surge in the adoption of the system is a recent phenomenon occurring within last 3-4 years under refinancing scheme through IDCOL, a number of issues were investigated in this study. First the issue of how the POs select their areas of operation and how or who among households self-select to acquire an SHS. The second refers to what capacity of SHS do people buy and the variables that affect it. Third, the observed outcomes of SHS adoption and fourth, what may be the policy implications of these findings.

9.2.1 PO and Household Selection

On the first point, it has been observed that the procedure of selection of POs by IDCOL follow certain general rules which means that whether a PO will be chosen depends on its institutional capacity assessment based on various indicators related to accounting and audit management, staffing, years of operation, assets position, experience of operation in off-grid area and credit operations experience and related other criterion. Even if the POs pass these tests, although the area they choose is also part of this exercise, it is still PO's own choice and as found they hardly operate alone. In most cases there are other POs operating in the area resulting in competition within the POs for market share.

On the other hand, the households may self-select themselves into the program but they are more often than not likely to belong to the better educated, higher income and land holding groups and also surprisingly female-headed households are comparatively more likely to opt for SHS. Furthermore, households where women are better educated have better chances of adoption of SHS.

9.2.2 The Choice of Capacity

The choice of the capacity of the system depends on when the choice was made, i.e. whether the adopters were early ones or have bought the systems more recently. Early adopters were of better income, asset and educated group. Early adopters thus could invest in higher capacity SHS because they could afford it and also because the energy services demanded could not be met by lower capacity systems. Over time, however, lower capacity and cheaper systems came on the scene and could meet energy service demand obtained previously only from higher capacity and costlier systems. This has opened up the market to poorer sections of people than previously. POs do target "credit-worthy" (meaning households with better means and thus able to repay loans without much problems) clients. But recent surge in sales of cheaper and lower capacity but technically somewhat superior models mean that this should not be a major concerns anymore and they should reach out to the more disadvantaged groups economically and socially, especially targeting women. In doing so, they should be more attentive to the problems of technical nature such as those related to battery disposal and concerns regarding charge controllers. In this regard, the issue of proper instructions and training to clients, particularly women, must not be lost sight off, particularly given the positive roles that women play.

9.2.3 Major Outcomes

The outcomes that have been examined are immediate and intermediate outcomes; the longer term sustainability outcomes could not be assessed as the system has not been in place for a longer period to reach maturity. The outcomes basically are welfare measures, not so much better economic opportunities and well-being. Some of the issues assessed include kerosene replacement and consequent lowering of indoor pollution as well as carbon saving, educational outcome of the school going children, incidence of preventable diseases among children and adults, fertility reduction and prevalence of contraceptive uses among currently married women, and women empowerment. It was found that SHS made positive inroads in all of these aspects of the participating households. But note that some of the impacts were indirect such as health and reproductive behavior changes through TV ownership facilitated by the use of SHS.

9.2.4 Role of Financing Method of SHS and Market Size

As the systems are marketed through the POs with subsidy and guaranteed refinancing scheme from the IDCOL, a natural issue arose as to whether the market would continue in the absence of such supports in future. It was found that subsidy has a positive impact on the price of the systems. Even though the subsidy is not directly given to the buyers, the purchasing households still receive a part of the subsidy in the form of lower price per unit. Thus, subsidy trickles down. Otherwise, withdrawal of incentives will increase the rate of interest from 12% to a minimum of 36% in order to maintain the current rate of return of POs.

The application of the WTP principle reveals that there is high potential of expansion of SHS with lower Wp due to inelastic nature of the demand. As the size of the existing market for the SHS is around 2 million, the market has created net benefits of more than Tk. 11 billions in the form of consumer surplus to the households using SHS systems.

9.3 Recommendations for Upscaling and Better Services

The system so far has operated fairly well. The management by the POs on the ground has delivered. But now that there are many POs vying for a slice of the market, problems have begun to emerge as Chapter 6 has indicated. Problems are of technical as well as probably managerial. Given these concerns, the following recommendations may be of use for further upscaling and providing better services:

a) IDCOL should strengthen its quality control and inspections to ensure the quality issues of recent installations do not go beyond control. IDCOL and POs should invest more in technician training to ensure quality installations. IDCOL's efforts of establishing photovoltaic testing facility in Bangladesh should be expedited so that the quality of the SHS components can be tested. Technical audit by independent third parties should be more rigorous and more frequent to detect problems early and appropriate follow-up measures by IDCOL to be ensured to address the problems.

b) POs and IDCOL should decide together how female-headed households and women in general may be provided more access to SHS and its services. Trainees may be chosen as Grameen Shakti does from among women for servicing SHS and thus be a source of income and empowerment for them. An on-going evaluation of the Grameen Shakti should be able to provide more precise recommendations on this issue.

c) IDCOL should be continuously on the lookout for better and tested technology which minimizes maintenance problems while may provide cheaper alternatives to present models for at least the same energy services compared to previous larger capacity models. The Wp choice based on price, technology and demand from buyers should coalesce together to this end. The IDCOL may review these issues periodically.

d) How far subsidy may be changed or withdrawn should be based on assuring POs a healthy return on their investment without burdening the consumers with high rates of interest.

9.4 Concluding Remarks

The future expansion of SHS is possible. But the need of the hour is to properly regulate and streamline the system, its technical, managerial and financing management and operations so that households benefit, get quality services while POs can make reasonable profit.

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