THE ROLE OF SOLAR HOME SYSTEM (SHS) IN SOCIO-ECONOMIC DEVELOPMENT OF RURAL BANGLADESH

A Dissertation
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Director

BRAC Institute of Governance and Development

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Mohakhali, Dhaka

Subject: Submission of Thesis Paper ‘MA in Governance and Development’

Dear Sir,

I am very happy of submitting the thesis paper entitled **‘**The Role of Solar Home System (SHS) in Socio-economic Development of Rural Bangladesh’, a report for partial fulfilment of the requirement for the degree of MA in Governance and Development Programme 2013-14 (MAGD-5).

This research is an attempt to measure the impacts of Solar Home System (SHS) and their role in socio-economic development of rural Bangladesh. The whole work is prepared on the basis of literature review, household survey, key informant interviews, various academic books and journals and internet also. Data are collected by household survey in remote rural villages and research findings and recommendations are prepared by analysis of the data. I have tried my level best to make this report comprehensive.

I hope you will find this report objective, precise and reliable. Please accept my gratitude for giving me such an excellent learning opportunity and clarify my limitations in preparing this internship report.

Thanking you with regards.

Yours Sincerely,

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Certification of acceptance

This is to certify that Md. Abdulla Harun, ID #13372007, BIGD, BRAC University, a participant of MA in Governance and Development Programme (MAGD-5) has completed his thesis paper entitled **'The Role of Solar Home System (SHS) in Socio-economic Development of Rural Bangladesh'** under my supervision. He has completed the report as a partial fulfilment of the requirement for the degree of **MA in Governance and Development (MAGD)** in BIGB, BRAC University.

The report has been prepared under my guidelines and is a record of the bona fide work carried out successfully.

Signature:……..

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ABSTRACT

This research is an attempt to measure the impacts of Solar Home Systems (SHSs) and their role in socio-economic development of rural Bangladesh. After a brief review of previous research works on SHS's importance, benefits and prospect, the study mainly focuses on the issues of SHS's impacts on socio-economic development. In this context, the literature of SHS related works is reviewed and afterwards, the methods and findings of an impact assessment study of SHSs in rural Bangladesh are described in detail.

The study is based on data from a survey of 90 households from three villages in Goffargoaw Upazilla of Mymensign district. From the research findings, some recommendations for SHS dissemination programmes in Bangladesh are made.

The research concludes with the following major findings:

- Introduction of micro-financing increases the SHS dissemination programme in remote rural areas of Bangladesh.
- The utilisation of SHS in rural area of Bangladesh exhibits clear positive impacts. However, the economic impacts of the SHS are very limited as households lack knowledge and proper training of diversified uses of SHS for income generation activities.
- As compared to economic impacts, social impacts are more pronounced. It is indeed true that improved household conditions for education, health, household work, access to information, communication, entertainment, and perception on safety bring about radical changes in the traditional social life and enhance quality life of rural people. On household level, children and women are benefited most as they spent most of their time within household premises using solar electric lighting and household appliances. At the same time, a large number of non-SHS households are being benefited indirectly from TV, radio, mobile phone, laptop and studying facilities from SHS households.
- Positive environmental impacts are also observed as the substitution of traditional lighting fuels save carbon dioxide emissions. But close monitoring of the old batteries collection and recycling system is essential for ensuring ecologically sustainable environment in rural area of Bangladesh.

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LIST OF ABBREVIATIONS

BBS	:	Bangladesh Bureau of Statistics
BCSIR	:	Bangladesh Council of Scientific and Industrial Research
BRAC	:	Bangladesh Rural Advancement Committee
BPDB	:	Bangladesh Power Development Board
BDT	:	Bangladesh Taka
CDM	:	Clean Development Mechanism
CO_2	:	Carbon dioxide
CSD	:	Commission on Sustainable Development
DC	:	Direct Current
DFID	:	Department For International Development
EPI	:	Expanded Programme on Immunization
FAO	:	Food and Agriculture Organization
GEF	:	Global Environment Facility
GOB	:	Government Of Bangladesh
GNESD	:	Global Network on Energy for Sustainable Development
GS	:	Grameen Shakti
GTZ	:	German Technical Cooperation
GHG	:	Green House Gases
ICT	:	Information and Communication Technology
IDCOL	:	Infrastructure Development Company Limited
IPCC	:	Intergovernmental Panel on Climate Change
JPOI	:	Johannesburg Plan Of Implementation
Kg	:	Kilogram
KWh	:	kilowatt hour
LGED	:	Local Government Engineering Directorate
LED	:	Light Emitting Diode
MDG	:	Millennium Development Goal
MW	:	Mega Watt
NGO	:	Non Government Organization
NRECA	:	National Rural Electric Cooperation Association
PV	:	Photovoltaic
PO	:	Partner Organization
REREDP	:	Rural Electrification and Renewable Energy Development Project
RSF	:	Rural Service Foundation
REB	:	Rural Electrification Board
RET	:	Renewable Energy Technology
SDG	:	Sustainable Development Goal
SHS	:	Solar Home System

SIS	:	Solar Irrigation System
SPSS	:	Statistical Package for Social Science
S.S.C	:	Secondary School Certificate
H.S.C	:	Higher Secondary Certificate
TV	:	Television
UN	:	United Nations
UNFCC	:	United Nations Convention on Climate Change
USAID	:	United States Agency for International Development
UNCTAD	:	United Nations Conference on Trade and development
UNCED	:	United Nations Conference on Environment and Development
UNDP	:	United Nations Development Program
US	:	United States
WP	:	Watt Power
WSSD	:	World Summit on Sustainable Development

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Energy is one of the most important basic ingredients required to alleviate poverty and to bring about socio-economic development of a country. Fossil fuel, sunlight, air, water source and nuclear power plant are the sources of energy throughout the world. Major energy source is still fossil fuel but the reserve is declining. Fossil fuel is being used though it emits greenhouse gases for global warming which is a threat to climate change and sustainable development. In this situation sustainable and secure energy are the major concern worldwide. Under these circumstances there is a transition underway in the energy sector. It is happening due to decline in fossil fuel availability, reduction of global emissions for mitigating climate change and energy security. Under the changed perspective renewable energy specially solar energy is becoming popular for it significance in contribution to global climate change and carbon trading prospect. United Nations Framework Convention on Climate Change (UNFCC) has taken initiative for Clean Development Mechanism (CDM). In this context, solar energy is becoming widespread source of energy throughout the world. To meet the growing demand for power in the industries, transportation and household use many developed countries are already using solar energy as renewable sources. This is not only meeting the bigger portion of energy demand but also providing significant socio-economic benefit and helping to maintain clean environment.

Bangladesh is a densely populated tropical country which has no sufficient supply of energy. At present around 62 percent (including renewable energy) of population has access to electricity, the per capita energy consumption is only 321 KWh per annum (Website: Power Division, GOB). Remaining 38 percent of the population depends on costly kerosene and natural sources. Bangladesh is still very centralized to its capital city. Many locations outside the capital do not get proper attention. Poor people cannot afford to have electricity for their daily activities. Many remote islands and highlands are not connected to national grid lines. Since expanding the national grid in those

isolated areas is very expensive and are not cost effective, solar energy could be an effective alternative to fulfill the electricity requirement in these off-grid areas. Recently use Solar Home System (SHS) is growing fast for solar electricity, though it has high initial cost. As a developing country Bangladesh and its people are suffering from power and electricity shortages. But the geographical situation and favorable climate conditions provide tremendous opportunity to utilize solar power for almost every aspect of our rural, urban, semi urban livelihood of Bangladeshi population.

1.2 Statement of the problem

Power system of Bangladesh depends on fossil fuels both in private sector and state-owned power plants. About 89% of generated power comes from carbon emitting natural gas, liquid fuel, coal and hydropower. The supply of natural gas is not sufficient to meet the demand. Current gas production capacity in Bangladesh cannot support domestic needs as well as wider electricity generation for the country. The existing reserve of oil and gas will be exhausted very soon. At the same time worldwide there is a demand for clean and sustainable energy. The need for developing renewable sources of energy like solar, wind, bio-mass, etc. has a greater sense of urgency. As a tropical country Bangladesh is endowed with solar energy. In this context solar energy is a reliable, affordable and secure energy for the country. But the present share of renewable energy for electricity production is only 0.5% of the total. Major people of Bangladesh live in rural areas. There is strong demand for power availability in remote villages. Bangladesh has embedded with plenty of solar energy. We have much potential to be a solar electricity-rich country. Institutional, financial and technological capabilities act as important factors for reaching a desired level of solar electricity production and utilizations. But we have lack of information and integrated research in this field.

Solar energy based rural electrification begun in the country in 1988 at Norshingdi. Power Development Board (BPDB), Rural Electrification Board (REB), Local Government Engineering Directorate (LGED), Infrastructure Development Company Limited (IDCOL) and a significant number of private sector agencies including Non Government Organizations (NGO) are involved in solar electricity development. Solar

electricity is increasingly being used in a wide range of off-grid applications. Since the introduction of SHS, Bangladesh has installed more than 2.2 million units. In this context measuring the socio-economic impact of SHS would be an illustration for designing rural development alternative energy-model in the country. The present study is intended to identify the factors associated with the implementation of solar energy and solar power system and how far it has been succeeded in reducing poverty in rural area of the country.

1.3 Objectives of the research

The objectives of the study are as follows:

- To assess the role of SHS on socio-economic development in Bangladesh.
- To develop some practical recommendations for improving access to SHS in areas where adequate power supply is constrained.

1.4 Research questions

The research will be carried out with a view to answering the following questions:

- What role SHS plays on socio-economic development in Bangladesh?
- What are the factors affecting basic socio-economic changes after having used SHS in rural areas of Bangladesh?

1.5 Methodology

The research is carried out by collecting data from both primary and secondary sources. Primary data are collected through household survey, interviews and secondary data are collected from journal, articles, case study through internet and from other relevant offices. Pre and post study design is used to measure role of SHS in socio-economic development of rural Bangladesh.

1.6 Rationale and scope of the study

Bangladesh has a large unsatisfied demand for energy. The country commonly experiences unmanageable demand-supply gap of electricity, specially during summer. The energy gap is one of the largest bottlenecks for economic growth in Bangladesh. By

some estimates Bangladesh economic growth could have been around 8% had it not been constrained by energy shortage. To sustain and progressing economic growth, government of Bangladesh is actively engaged in energy crisis management. The national energy policy has the explicit goal of supplying the whole country with electricity by 2021. Bangladesh adopted renewable energy policy-2008, which requires having at least 5% power from renewable sources in the energy mix by 2015 & 10% by 2020. Till now, national capacity of renewable energy based power is approximately 90 Mega Watt (MW) and it mainly comes from solar energy.

SHS can transform the lives of people in the rural area. Solar power may be a way of development providing solar electricity solutions for households, agriculture, healthcare, education, telecommunication, rural streets and marketplaces. Government, development partners, research institutions, NGOs and private organizations are working for turning Bangladesh into an energy-efficient country through the utilization of untapped solar energy. Solar power is the most potential source among the renewable energy resources in Bangladesh. By taking appropriate policy, rules and regulation, it is possible to mitigate country's growing electricity demand using solar energy. The current research therefore will identify the factors associated with utilization of SHS and it socio-economic impact in rural areas.

1.7 Significance of the study

Bangladesh is a tropical country of enormous solar energy. But a very little amount of it is used. Though the inception of SHS in Bangladesh was in 1988 but it was untapped for a long period. By this time various applications of solar electricity is seen throughout the world. Now-a-days Solar Panel provides electricity for solar vaccine refrigerator, solar water disinfection (SODIS), solar food drier and solar pasteurization. This helps for reducing waterborne diseases. Solar phone, solar Wi-Fi, solar radio increase rural communication, reduces transport cost and reduce digital divide. Beside solar cooker and solar water heating, reliance on traditional fuels such as wood or charcoal, reduces indoor pollution and carbon emission. This increases the quality of life in rural areas, improve health and education, reduce oil dependency, increase local employment and reduce deforestation. Solar power activities lead rural development.

Due to lack of information and study SHS is used only for household lighting in Bangladesh.

Solar irrigation technology is also getting popular in Bangladesh. As agriculture based country, using solar power irrigation system would be a major driving force for rural development. Government organization, Academic institutions, NGOs and private companies are involved in renewable energy sector in the country. Researcher, policy maker, development partner in Bangladesh acknowledged the immense prospect of solar electricity for rural transformation. But there is no integrated study of the prospect and scope of solar electricity for socio-economic development in rural area of Bangladesh. As of now there is very limited academic study on the socio-economic or environmental impact of solar electricity in rural area. So the study would assist the concern policymakers and implementers to take necessary measures for sustainable rural development in Bangladesh. Identifying the new innovative use of solar electricity in rural areas would help the implementers for effective planning and undertaking programs. Moreover it will also help for new technology transfer in rural areas.

1.8 Limitations of the study

During field work some limitations are encountered. These are:

Non-availability of Documents: One challenge is the difficulty in gathering documented information from officials. In some cases documents may not be found readily available and considered confidential.

Limited time: Time is another constraint in the field work. The time given for the data collection is too short. Qualitative study requires more time to analyze data while gathering information. At the same times it may also need extra time to restructure its design in the light of new developments and insights.

1.9 Outline of the study

Following the introduction the second chapter of this report will focus on review of selected literature and conceptual overview of SHS in socio-economic development. In third chapter, it will discuss the methodology of the research. The fourth chapter is analysis of the data, results and discussions. The fifth chapter is conclusions and recommendations and of this report.

CHAPTER TWO

REVIEW OF SELECTED LITERATURE AND CONCEPTUAL OVERVIEW

2.1. Introduction

Affordable, accessible and secure supply of energy plays a driving force for socio-economic development of a country. A number of recent studies reveal how rural electrification from solar power in particular helps in socio-economic development of the country in various ways. In this circumstance, solar energy is widely perceived as a promising technology for electricity generation in remote location of the developing countries. This chapter attempts to focus on the review of selected literature, key concept of solar electricity as driving force for socio-economic development, issues and factors effecting socio-economic development like household income, health, education, agricultural production, access to information and other infrastructural services.

2.2 Rural electrification

Rural electrification means providing easy access to affordable electricity in rural area. Majority of population in developing counties lives in rural areas, and rural electrification is perceived as the key driver for socio-economic transformation. Widespread electrification of rural areas started during 1930s, mainly in the United States and the more economically advanced European countries (FOLEY, 1990, p. 6). United State Agency for International Development (USAID) designed a model of rural electrification in the early 1970s and the model was replicated in developing countries (BARNES, 1988, pp. 17-19). Now-a-days rural electricity dissemination can be achieved by either centralised supply or decentralised approaches. The centralised approach refers to connecting villages and remote areas to a national grid, which is often owned and operated by a public utility (GOLDEMBERG 2000: 375). Rural electrification through centralised approach involves high capital cost. As a result, remote, less-densely populated areas remained far behind the access to regular and uninterrupted electricity. In contrast, decentralised approaches for rural electrification,

access to power is not provided by a national grid, but instead generated locally near the place of consumption. Decentralised power supply may be of two types: Mini-grids and Stand-alone systems. The most common energy sources for mini-grids are diesel generators, small-scale hydropower, small photovoltaic power stations, or diesel-wind hybrid systems (FOLEY 1990: 43-65). Stand–alone systems generate electricity right next to the place of consumption, and are almost exclusively used for small-scale energy demand on household or small business centres. Most common technologies for rural electrification are diesel generators, solar photovoltaic (Solar Home System) and small wind generators. A study undertaken by the World Bank for 11 countries reveals that rural electrification results great benefits such as improvements of health facilities, better health from cleaner environment as households reduce use of polluting fuels for cooking, lighting and heating, improved knowledge through increase access to television and better nutrition from improved knowledge and storage facilities from refrigerator (World Bank. *The Welfare Impact of Rural Electrification,* 2008, ch.5, pp. 39–52).

2.3 Solar energy as a source of sustainable rural electrification

Renewable energy sources such as solar energy, wind or hydropower are available on an indefinitely sustainable basis, whereas fossil resources (oil, coal, gas) are in finite quantities. The Agenda 21 enacted on the International Conference on Environment and Development in 1992 in Rio de Janeiro put focus on the importance of renewable energy in the context of climate change. In 2001, the 9th session of the Commission on Sustainable Development (CSD-9) gave special attention to energy. It concludes that "Energy is the central in achieving the goal of sustainable development (*Global Network on Energy for Sustainable Development,* GNESD, 2007, ch.1, pp. 1–5). A study by the World Bank in 2005 reveals that - assuming availability of the respective renewable energy source – Renewable Energy Technologies (RET) are the least cost option for off-grid stand-alone electrification in rural areas. According to Global Network on Energy for Sustainable Development (GNESD, 2007), without adequate supplies of affordable energy, it is difficult to improve health, education and reduction of poverty.

2.4 Importance of solar energy for rural electrification in Bangladesh

In 1971, the year of independence of Bangladesh, only 250 out of 87,928 villages had access to electricity (BARAKAT, 2004). Government of Bangladesh (GOB) committed itself to develop a programme for providing electricity to rural areas. Article 16 of the Constitution of Bangladesh states: “The State shall adopt effective measures to bring about a radical transformation in the rural areas through the promotion of an agricultural revolution, the provision of rural electrification, the development of cottage and other industries and the improvement of education, communications and public health, in those areas, so as progressively to remove the disparity in the standards of living between the urban and the rural areas” (GOB, 2004). Bangladesh Power Development Board (BPDB) was formed to operate and expand the electricity network, which mainly concentrated on electrification of urban centres. To increase rural electrification National Rural Electric Cooperative Association (NRECA) was commissioned to conduct an extensive study. NRECA developed a master plan emphasising on the provision of electricity for agricultural mechanisation, irrigation and rural industries. The master plan was adopted in 1977, closely followed by the establishment of the Rural Electrification Board (REB) in the following year (BARNES 2005: 84). By January 2014, more than 50,194 villages had been electrified through the REB programme serving more than 84, 22, 246 domestic line (REB, website) and 53.34% people get access to electricity service and the rest 46.66% depends on kerosene and other sources (BBS, 2008).

The REB has set a goal to bring all villages of Bangladesh under electrification by 2020. However, it has to be noted that the electrification of a village does not necessarily mean that all households will immediately get a connection, as affordability of the initial connection cost creates a problem for certain number of households. Therefore, only a small minority (10%) of rural Bangladeshis have access to electric power. Furthermore, the quality of supply is often unsatisfactory due to frequent load shedding and voltage variability (MIYAN 2004: 42). In more remote areas, distribution line set-up is more costly due to its landscape dominated by extensive areas of water, regular flooding, hilly and certain regions of river islands. In this situation decentralised

electricity supply with RETs might represent a viable and cost-effective alternative to conventional grid-based electrification.

Natural gas reserves estimated to be exhausted very soon and Bangladesh's petroleum consumption being totally import-based, increased use of renewable energy sources seems to be a reasonable step for the development of a sustainable long-term energy scenario (ISLAM 2004: 9). Even though Bangladesh's physical landscape is shaped by enormous amounts of water, the potential for hydroelectric power generation is quite limited. Country's only hydroelectric plant, Karnafuli power plant, has a total generating capacity of 230MW, accounting for about 5% of the total installed capacity of electricity in the country. The construction of the dam and the reservoir for the Karnafuli power plant led to severe negative environmental and social affects creating long drawn social unrest among the local population. Again electricity generation from wind power is also more limited in Bangladesh for scarcity of usable wind speed. Beside, generation of electricity from biomass such as animal waste or crop residues are still in the early stage of development and testing.

Bangladesh is geographically located in a favourable position for harnessing sunlight, available abundantly for most of the year. Average daily radiation of solar energy is about 4.5 kWh per square metre making it technically quite feasible to use photovoltaic energy for electrification purposes (ISLAM 2005: 79). Experience has revealed that Photovoltaic (PV) electricity seems to be more appropriate for isolated rural areas away from conventional gridlines (ISLAM 2005: 79). He also states for the future that with enough political support it would be possible to 'Plug even the remotest rural areas of Bangladesh to the sun' (ISLAM 2005: 76). From the above circumstances, the use of solar energy (Solar Home System) is the most feasible option for rural electrification in Bangladesh.

2.5 Solar Home System (SHS)

The direct conversion of sunlight into electricity is called photovoltaic solar energy conversion. An essential component of Photo Voltaic (PV) system is the solar cell, in which the photovoltaic effect takes place. When light falls on the semiconductors of the

cell, it produces a small electric current. Photovoltaic modules, or panels, consist of a number of cells connected together to provide voltages and currents high enough for practical use. More common in rural electrification programmes is the use of solar PV as stand-alone systems in households, social institutions, or places of productive or business activities. Generally, the system is referred to as 'Solar Home System' (SHS). The SHS providing load is low (below 100 W), but can be sufficient for powering of lights, radios, television sets, and to refrigerate medicines at rural clinics. Even though SHS seems to be expensive at first glance, it is cost-effective in providing electricity at small scales in areas without access to grid electricity or any other renewable energy source. Its application can furthermore be reasonable where demand is characterised by very low levels or the procurement cost of fuel is very high (GOLDEMBERG 2000: 376, SUDING et. al 2004: 72). However, with rising fuel prices SHS technologies may become more cost-efficient than off-grid alternatives based on fossil fuels.

2.5.1 SHS electrification approach

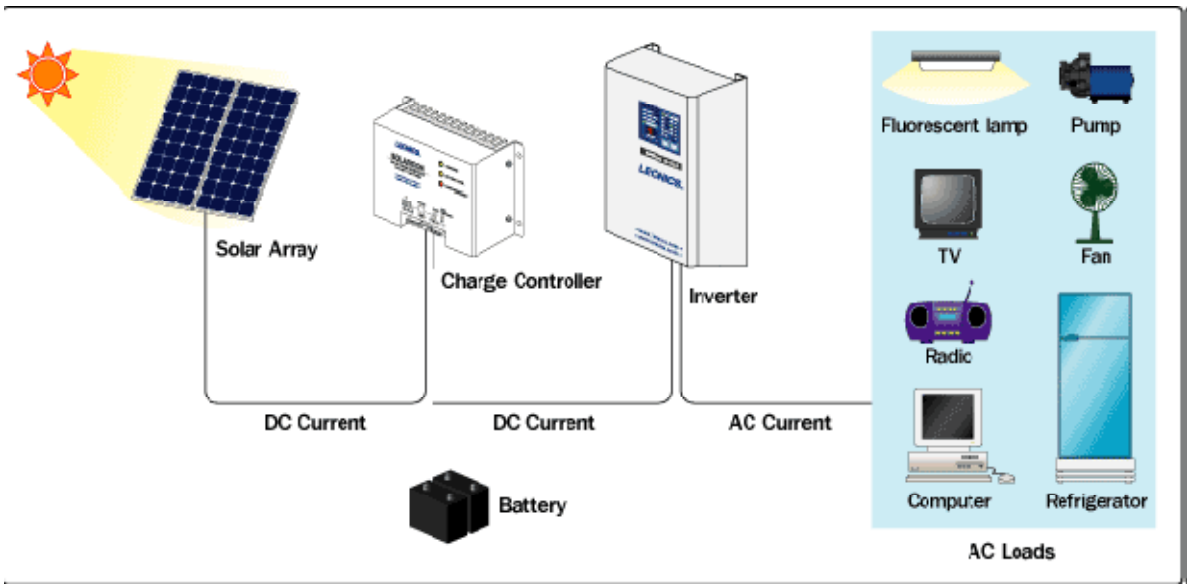
SHS is highly relevant for decentralised rural electricity supply in developing countries in general and Bangladesh in particular. For decentralised rural electrification purposes in developing countries, the SHS is the dominant practical application of PV technology (CAMPEN et al. 2000: 16-17). This is also the case for Bangladesh, where SHSs are by far the most important technology for decentralised electricity generation from a renewable energy source.

2.5.2 Technical background of SHS

Solar Energy is the energy from the Sun. It is often called 'alternative energy' to fossil fuel and has been used by humans for thousands of years. The photovoltaic/solar module (Figure-1) converts the sunlight into electricity. It typically has a capacity of between 20 to 100WP. The battery stores the electric energy for utilisation at night or during cloudy weather. In many countries, cheap automotive batteries are used for this purpose, although they are technically not well suited for PV applications. The charge controller is a device that manages the electric flow through the system, and protects the

battery from damage. It alerts the user as soon as the battery needs charge or when the module is not working properly. Wires and connected switches distribute the electricity within the system and to the load such as lights or electric appliances.

Figure-1: Solar panel and its applications



Typical SHS operate at 12 volts direct current (DC) and use efficient fluorescent or Light Emitting Diode (LED) lamps and appliances to make best use of the provided power (HANKINS 1993: 10). A typical 50WP SHS can provide enough power to operate four small fluorescent lamps, and a small 15-inch black-and-white television for up to five hours (CABRAAL et al. 1996: 8). However, the range of other appliances is often limited.

2.5.3 Progression of worldwide SHS dissemination

The use of solar electricity increased at the discovery of photovoltaic cell in 1839 by French physicist Edmond Becquerel. Successive researchers have developed cells with more efficiency. The first interest in solar technologies for rural stand-alone electrification arose in the 1970s. An economic breakthrough occurred when Dr. Elliot Berman was able to design a less expensive solar cell bringing the price down from $100 per watt to $20 per watt. This huge cost savings opened up a large number of applications that were not considered before because of high costs. The 1973 oil

embargo and 1979 energy crisis caused a reorganization of energy policies around the world and brought renewed attention to developing solar technologies. Between 1970 and 1983 photovoltaic installations grew rapidly, but falling oil prices in the early 1980s moderated the growth of solar photo volt from 1984 to 1996. By the mid-90s, various initiatives were launched to scale up into large SHS commercialisation and government-sponsored dissemination programmes. Since 1997, solar electrification has accelerated due to supply issues with oil and natural gas, global warming concerns and the improving economic position of PV relative to other energy technologies. By the end of 2005, 2.4 million SHSs had been installed worldwide with an estimated annual installation of more than 2,70,000 systems (REN 21 2006: 12).

Dissemination of SHS depends on affordability. According to F. D. J. Nieuwenhout adequate service infrastructure is required to make projects viable. Household choice in system sizes is often too restricted in donor-funded projects. Smaller systems sold for cash can be a good alternative to credit systems by offering to increased affordability (*F.D. J. Nieuwenhout, et al, 200; 9: 455-474*). Depending on their size, prices of SHSs can vary between US$ 100 and US$ 1,100. There are also significant price variations for different countries observable. Local prices depend on factors such as duties, taxes, and subsidies, the scale of manufacturing and assembly processes, the scale and cost of marketing and other services, the degree of competition, capacity utilisation in manufacture, sales & servicing and the cost of funds for working capital and capital costs. The other major issues to be considered are the high initial costs, the establishment of a responsive and sustainable infrastructure and the guaranteeing of quality products and services. Reducing the market prices of SHSs by influencing the above factors is an important strategy of many SHS dissemination programmes (CABRAAL et al. 1996: 8-9). In recent years most of the global growth in SHS sales has concentrated on a few Asian countries, namely India, Sri Lanka, Nepal, Bangladesh, Thailand, and China. In these countries, the problem of affordability has been overcome either with micro-credit or by selling small systems for cash.

2.5.4 SHS dissemination in rural Bangladesh

The first experience with SHS in Bangladesh was gained from 1997 onwards when the REB implemented a French-funded pilot project for the electrification of 850 households on a remote river island in the district of Narsingdi (ISLAM 2004: 18). This pilot project was implemented using the so-called 'fee for service' model. The project proved the technical feasibility and socio-economic acceptability of SHS in rural areas of Bangladesh. Experience from this project turned out to be very useful for the design of later SHS dissemination programmes (ISLAM 2004: 18).

Encouraged by the success of the REB pilot project in Narsingdi, NGOs soon went ahead with their own SHS dissemination programmes. First commercial activities regarding SHS was initiated by Grameen Shakti (GS), which was established in 1996 as an NGO member of the famous Grameen family of organisations to promote renewable energy services in remote rural areas of Bangladesh (QUDDUS 2003: 123). In 1997, the agency started selling SHS by following 'cash sale' and 'credit sale' approaches.

A new phase of SHS promotion started in 2002 with the implementation of the 'Rural Electrification and Renewable Energy Development Project' (REREDP), which is jointly financed by the World Bank, Global Environment Facility (GEF) and German Technical Cooperation (GTZ). Infrastructure Development Company Limited (IDCOL), a government-owned entity, disseminates SHS through 47 partner organisations (POs), namely experienced NGOs such as GS, Bangladesh Rural Advancement Committee (BRAC), Rural Service Foundation (RSF) as well as a number of smaller NGOs and private enterprises. The POs sell SHS to households and small businesses mostly through 'cash sale' and micro credit schemes. Furthermore, the POs select the project areas, install the systems, and provide maintenance support. IDCOL provides refinancing facilities to the POs and channels grants to reduce the cost of the systems therewith making them more affordable to rural customers. Furthermore, parts of the grants are used to support the institutional development of the POs (IDCOL, 2014). Besides giving financial support, IDCOL sets technical specifications for the solar equipment, provides technical, logistic, promotional and training assistance to the POs and monitors the PO's performance (ISLAM et al. 2003: 142-143). Due to unexpected

high SHS sales and the popularity of SHS, IDCOL has brought more than 26,28,426 rural households under the solar power system. The IDCOL programme is one of the fastest growing renewable energy programmes in the world (IDCOL, 2014).

2.6 SHS electrification as driving force for socio-economic development

In September 2000, the United Nations General Assembly's committed to a global partnership to achieve Millennium Development Goals (MDGs) by the year 2015. Reducing rural poverty through rural development is viewed as a key requirement to achieving these goals and underpinning the need for expanding access to modern energy technologies (*UNCTAD/2010:2*). New and renewable sources of energy have received a great deal of attention since the World Summit on Sustainable Development (WSSD) held in Johannesburg in 2002 as Johannesburg Plan of Implementation (JPOI). The JPOI reiterated support for Agenda 21, the outcome document of the 1992 United Nations Conference on Environment and Development (*Website: UNCED*). MDG 7 – ensuring environmental sustainability – promotes renewable energy technologies as a way of expanding access to these services. In this connection Solar, wind, and hydroelectric power get popular for not only producing minimal carbon emissions but also help reduce poverty through improved energy access in underserved areas. The availability of affordable, secure and environmentally responsible energy supply is therefore the main key to reach the MDGs and to decrease the welfare gap on the global scale (*Carsten Ahrens, 02*).

Economic development depends on energy. In general, energy is not considered as a basic human need. In the past, rural energy, in particular, was not widely accepted as a basic need like water and food in the development circles (Clancy, 1999 cited by Cecelski, 2003). Nonetheless, energy, particularly electricity is required for meeting basic needs such as health, agriculture, education, information and other infrastructural services and shows a clear correlation with per capita income and human development index (Anderson, 2000; Gillis et al, 1992; Rehling, 2002).

Although rural electrification does not necessarily reduce poverty, its relationship to poverty reduction cannot be denied. Now-a-days solar electricity is a way of development providing electricity solutions for households, agriculture, healthcare,

education, telecommunication, rural streets and marketplaces, as well as government and private institutions. It is benefiting rural life creating income-generating scope and activities. This is also saving environment by replacing fuel lamps and facilitating energy access for the remote localities. Apart from this, solar energy is relentlessly active to involve in many innovative application in the market. In this regard, increased use of solar energy has been identified as alternatives to grid-electricity supply in remote rural areas for poverty reduction (World Bank, 2003). Recently the link of energy to sustainable development and poverty reduction has been intensified in the world. It is understood that unavailability of electricity services in rural and peri-urban areas is usually associated with poverty and it is among the most serious problems confronting everybody (United Nations development Pgrogram, 2004). At the nineth session of the United Nations Commission on Sustainable Development (CSD-9) renewable and rural energy were identified among the key energy issues for sustainable human development (Chaurey et al, 2002). Several authors have provided analysis of the link between energy (electricity) and major global issues such as health, education, water, gender etc (Cecelski, 2003; DFID, 2002; UNDP, 2004). Rural electrification may be considered as basic necessity to improve socio-economic condition in rural areas. Arne Jacobson provides an assessment of the social significance of rural electrification with solar energy in Kenya. In the early 1980s only about 4 per cent of rural households in Kenya were connected with electrical grid. As of now, solar electricity has emerged as a key alternative to rural electrification. The study illustrates that the benefits of solar electrification are captured primarily by the rural middle class. Solar electricity plays a modest role in supporting economically productive and education-related activities, but “connective” applications such as television, radio and cellular telephone charging often receive a higher priority. Solar electrification is closer tied to increased television use, the expansion of markets, more rural-urban communication, and other processes that increase rural-urban connectivity than to poverty alleviation, sustainable development or the appropriate technology movement (*J. Arne* 2007). Vijay Laxmi and others found that in the case of bio-fuel use, time spent and hardship suffered in fuel collection, health impacts suffered from air pollution, increased burden of cleaning utensils, walls, floors and clothes, ecological changes and so on, are negative externalities (Laxmi,

Vijay 2003). Tarujyoti Buragohain studied the impact of solar energy in rural development in India. Use of kerosene is reducing in rural areas was found in the study. Nearly 53 to 69 percent reported that there is significant improvement in their children's education, and 37 to 78 per cent reported that there is improvement in the standard of living after the installation of solar lighting. Beneficiaries now spend more time on income generating activities. Crime rate has also declined due to availability of solar street lights in the village (Tarujyoti Buragohain, 2012).

In Bangladesh, Barkat (2002) carried out a very rigorous study on the economic and social impact of a rural electrification program on where they found that access to rural electrification has a significant impact on the reduction of both income poverty and all dimensions of human poverty (health, education and women empowerment). The study also found that rural access to electricity has a deep-rooted impact on agricultural development, industrialization, business and commercial activities. In addition, it has an impact on human capital formation through knowledge building mediated by electricity-driven media exposure (Barkat, Abul et. Al, 2002). Solar energy technologies (solar irrigation, domestic lighting system) create income-generating activities for male landless and marginal farmers and for women from such households, while reducing environmental problems, like deforestation and indoor air pollution from cooking with poor quality fuels. The use of one electric light bulb is far superior to kerosene lamps and candles (Wahidul K. Biswas, 2001, 333-344). Chowdhury conducted a study to find out the economic and social impacts of sustainable rural energy on poor people and governance and management of two infrastructure project which use solar energy. The study found that providing electricity through solar energy has a multidimensional effect on rural livelihood. It not only improves the living standard of the rural people but also improves access to information, better health for women and children and an extension of indoor income generating activities. However, poor maintenance, lack of technical knowledge and training hampered the operation and repairing functions of solar energy technology in the rural community. For improving effective management of solar energy technologies, there is a need to increase end-user awareness of system use, end-user capacity to troubleshoot problems and level of service, quality and timeliness of repairs (H U Chowdhury, vol 17, no 2). Khan studied the utilization of

renewable energy for world poverty reduction as well as for meeting the objectives of the MDGs. His study shows some links between the development of energy services and meeting the MDGs in the context of reducing poverty, achieving primary education, promoting gender empowerment and ensuring environmental sustainability (Khan. S., 2006).

The basic applied forms of solar PV in rural Bangladesh are solar home lighting systems installed in households and local market/bazaar (hat). The success of solar PV micro utilities is attributable to several factors. These include the acceptability of a daily tariff structure and the rate as well as proper marketing that explains the solar-energy-based system's capabilities, benefits, and constraints in comparison to other available options to potential users. Providing electricity for meeting lighting needs of households and rural markets can yield positive results, including improvements in quality of life and increasing income and employment opportunities. There is also a positive linkage between application of solar PV and meeting the objectives of the united Nation's Millennium Development Goals (Faisal Ahmmed & Dilder Ahmed Taufiq, 2008, vol. 3, pp. 93–103). Solar cells the most frequently used form solar technology can be used for a wide variety of applications such as solar power plants, in the rooftops of buildings, on street lights, etc (SHAKIR-ul haque Khan et al, 2012). Quality of life is simply life goals of socio-economic development that can be achieved through better education, health, access to information, indoor lighting, among others. Significant impacts of solar PV systems include better quality of light; indoor smoke and fire hazards from kerosene lanterns are reduced (Posorski, 1996; Obeng et al 2008b). Furthermore solar PV electrification contributes to improve quality of life in off-grid rural communities through the direct effect of the technology on household wellbeing and enterprise income (Cabraal et al, 1996; Fishbein, 2003; Martinot et. al., 2002; Posorski, 1996).

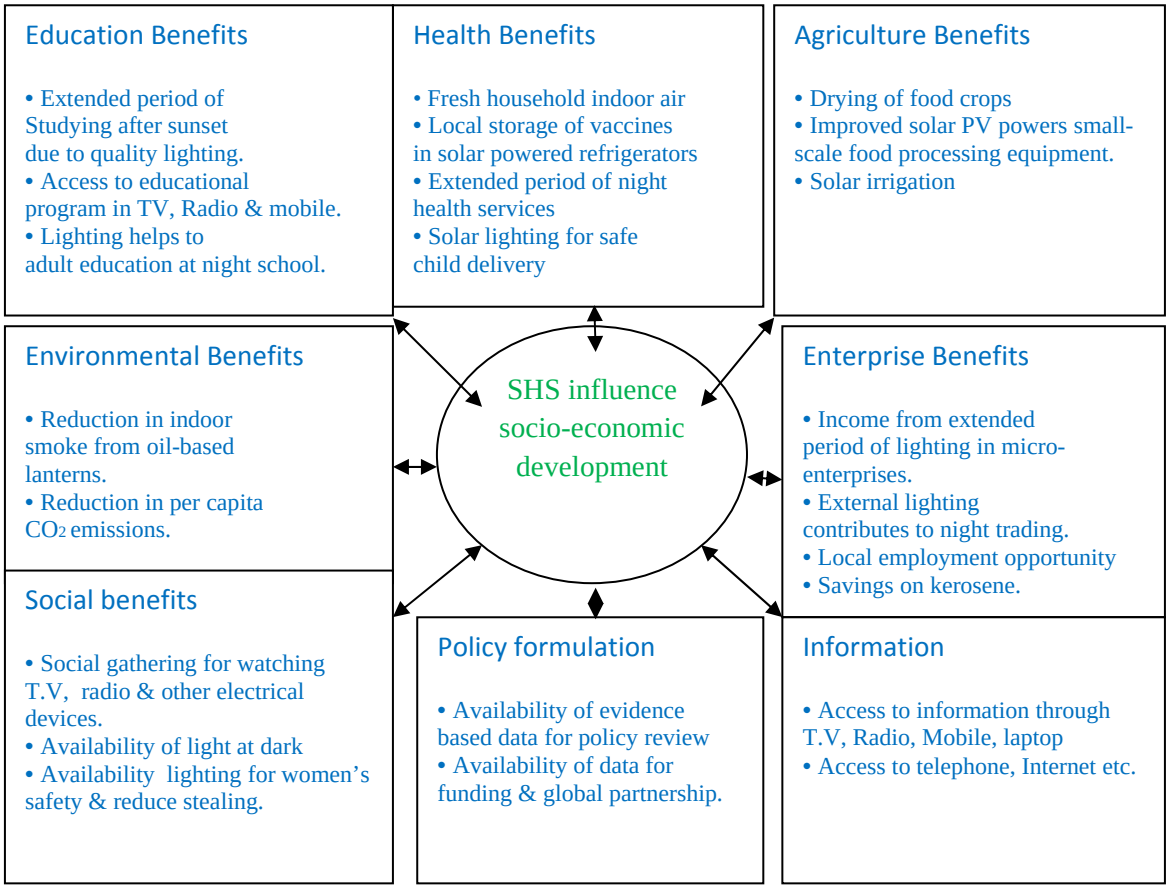
The prime role of solar energy is transforming the lives of people in the rural area. Solar electrification can improve the quality of life of rural households through positive impacts that cannot easily be expressed in monetary terms. Installing solar power in homes helps families with a variety of tasks. By using a SHS children's can study for a longer period and they also can watch television and recharge their cell phone handsets. From above discussion, a common key finding is that energy alone cannot initiate

development and reduce poverty. It must be linked to development strategies for education, health, agriculture, access to information and infrastructure for socio-economic improvements. Within this context, the linkages of solar energy strategies to socio-economic development have been under-explored.

2.6.1 SHS and socio-economic development framework

Figure-2 is a framework of SHS and socio-economic development. It is an illustration of the multi-sectored linkages of SHS influence on quality of life in off-grid rural communities. It indicates social and economic benefits that may be achieved to rural beneficiaries by using SHS. The framework focuses on specific area of education, health, agriculture information, environment and micro enterprise linkages with several sectors through solar electrification in rural area. It is based on a combination of models and findings from relevant literature (DFID cited in UNDP 2004; Fishbein, 2003; Martinot, 2004).

Figure-2: SHS and socio-economic development framework



2.6.2 SHS promotes education

Education plays an important factor for eradication of poverty. Any effort that contributes to promote education is welcome everywhere. Solar lighting provides higher quality illumination than kerosene lanterns, extended study time as well as better comfort and safety. In solar light children enjoy better facilities for education. It can improve educational opportunities and provide entertainment. It is reported that solar electricity lighting in remote rural schools permits children to extend their studies in the evening (Allderdice and Rogers, 2000; PPIAF, 2002; DFID, 2002; UNDP, 2004). For many children, especially girls in rural areas the lack of electricity translates into a missed opportunity to attend school because they are overloaded with menial tasks such as fetching water and fuel during daylight hours (Allderdice and Rogers, 2000). Furthermore, solar PV lighting enables access to radio, television and internet, which increase education opportunities and allows distance learning (DFID, 2002; UNDP, 2004). Children in electricity less rural areas spend significant portion of their time in household's activities during day time. They do not have light to study at night. A few hours of electricity to study at night students can result in major improvements in their performance (*United Nations. The Energy Challenge for Achieving the Millennium Development Goals,* 2005, pp. 15-49)**.** If rural electrification policies, programmes and plans integrate SHS as an alternative source for the supply of electricity services for remote rural communities, children will get access to lighting in the evening to extend their studies.

2.6.3 SHS facilitates health benefits

Public health is a critical sector in off-grid communities. Solar energy can have a significant impact on livelihoods in rural areas. The replacement of kerosene

lanterns with SHS reduces indoor air pollution, which affects the health and wellbeing of rural families. World Bank has classed indoor air pollution in developing countries among the four most critical global environmental problems (Cecelski, 2003: 27). Indoor air smoke contributes to respiratory infections that account for up to 20 percent of the 11 million deaths of children each year (DFID cited by UNDP, 2004). Solar energy helps to improve health by reducing acute respiratory infection and conjunctivitis, commonly caused by indoor pollution (Cabraal et al, 1996). But there is lack of quantitative data on the likely proportion of reduction of indoor air smoke from kerosene lantern by using solar light.

Solar electric water pumps can provide clean water, reducing the effort need for collection. Solar electricity can make possible the refrigeration of vaccines and operation of medical equipment in rural health clinics. A healthy life is a key indicator in the capability approach to poverty (Pearce, 2002). Women in labour need clean light to have safe child delivery at any time. In a rural clinic where there is no electricity, women deliver under very uncomfortable conditions due to the lack of essential equipment, medical facilities and poor visibility after sunset. So it is necessary to re-emphasize the need for pragmatic policies to set up environmental health–friendly technologies like SHS to operate remote rural health centres efficiently.

2.6.4 SHS catalyses information communication technology

Solar electricity provides alternative power to meet the information and communication needs in off-grid rural and peri-urban communities. By powering radios, televisions or computers with SHS, rural households are able to access health, education, business, agricultural and environmental information to better their standard of living (Greenstar, 2004; Amankwaah, 2005). Internet-connected community centers and rural business centers are emerging areas where SHS is

used to power the equipment for the delivery of information and communication technology (ICT) services in rural and peri-urban communities in Bangladesh. In remote Union Digital Centres SHS provides wireless and internet-based services. It has created new jobs and skills, strengthen local institution, affirm independence and generate extra incomes that gradually reduce rural poverty.

2.6.5 SHS promotes agriculture and rural enterprises

Agriculture plays a vital role for food security and economic development. Securing access to water plays a strategic role in ensuring agricultural production (FAO, 2005). In this regard, solar PV water pumping can supply water for dry land irrigation. Addressing energy issues related to agriculture and off-farm activities can help to increase prospects for income generation in rural households/enterprises by providing energy for irrigation, food processing, food preservation and many types of manual production during evening hours (Etcheverry, 2003; Martinot, 2004). Power shortage and low voltage affect irrigation for the electricity operated pumps causing lower production of crops. Besides diesel operated pumps require increasing price for petroleum. Considering the energy crisis of the country and products across the globe, it is important to explore alternative energy sources for irrigation to ensure both food and energy security (*Website: Power division*). Solar Irrigation System (SIS) is an innovative, economic and environmentally friendly solution for the agro-based economy of a country like in Bangladesh. SIS allows farmers to crop paddy more than once in a year and replacement of part of agricultural pumps with Solar PV technology could also offset considerable GHG emission (Hridkamol Biswas & Faisal Hossain, 2013, 05).

SHS helps micro-enterprises to generate additional income by extending their working hours after dusk (Grameen Communications, 1999; Allderdice and Rogers, 2000; DFID 2002). With solar power people can operate rice-grinding mill in rural area. Small rural stores can also expand their inventory by adding

items that can be preserved using solar-powered refrigerators (Allderdice and Rogers, 2000, Etcheverry, 2003). For example, solar PV-powered icemakers can assist village micro enterprises in fishing, sale of ice cubes and cold drinks. It also creates business as manufacture, wholesale suppliers, retails sale business, service business such as system design, system installation, consulting service etc. Many organization have taken the assembling, repairing of solar accessories to the rural areas, creating green jobs for rural people. Besides domestic use, people are harnessing solar power to run small businesses**.** Introduction of SHS in the rural areas creates an opportunity for the villagers to open up small businesses like mobile phone charging shops, computer training centres, TV and mobile shops. But, in the literature very few published data are available in quantitative terms of additional incomes likely to be generated by different solar-electrified enterprises and therefore there is need for further research.

2.6.6 SHS empowers women and marginalized groups

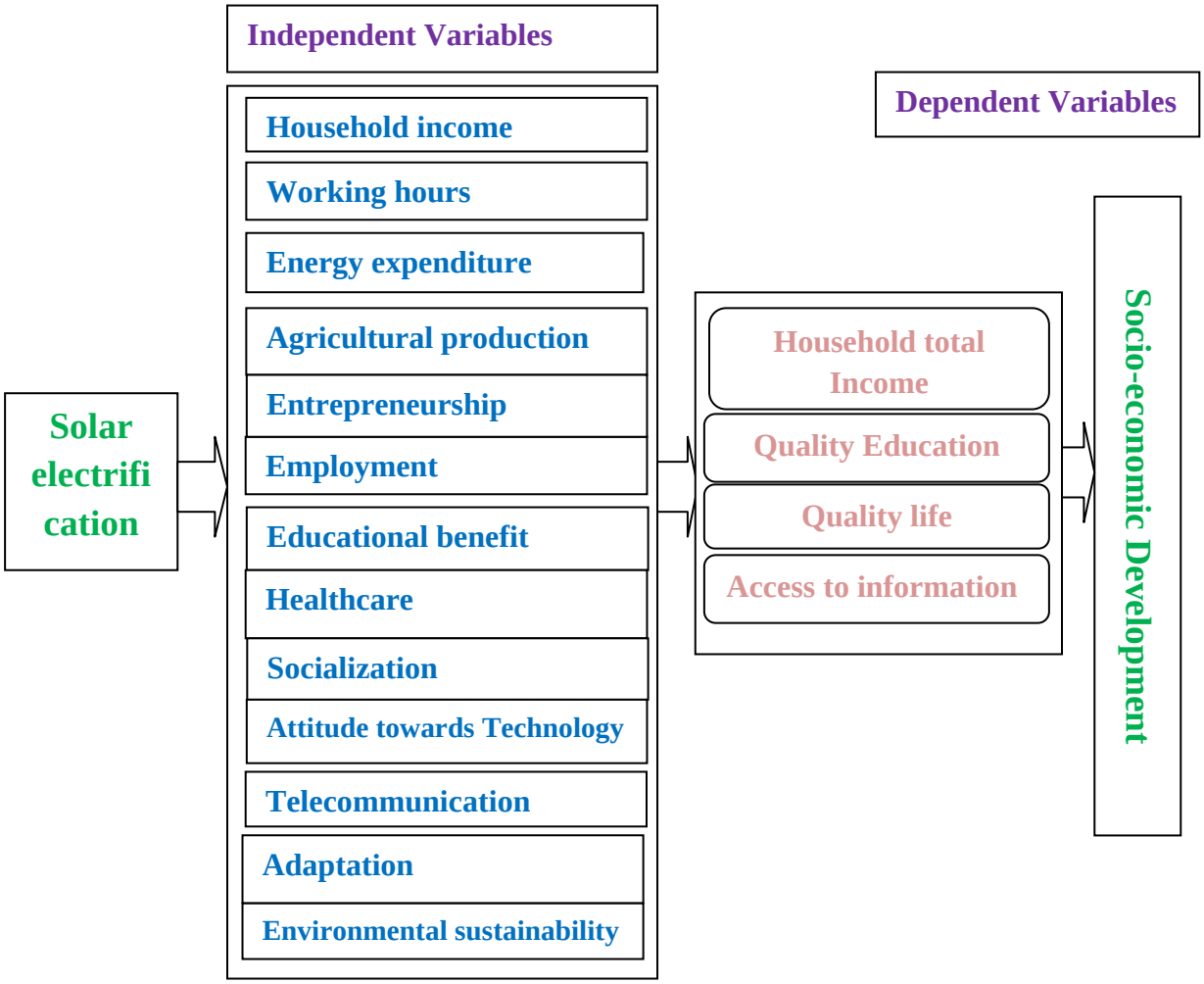
Solar PV technology program in remote, rural & off grid villages have a tremendous impact especially on women and children. Women and children in particular will have more time for education, leisure and economic activity. Women can enjoy hassle free lightening and earn extra money by utilizing their time after sunset by sewing or poultry farming. Many women are involved in repair, maintenance and sale of solar accessories. It made decent jobs for women right in their villages (*Khalid Md. Bahauddin, et al, 2010: 104)*. Women in rural areas spend 2-6 hours a day for collecting fire wood due to lack of electricity (CABRAAL, A., M., *et al*, 1996**).** Solar energy is public goods. Poor people in remote and isolated area can use modern technology by solar energy application. Using mobile phone, solar power-based computer and internet, people can get government decision easily. They can participate and raise opinion in many government issues. Marginalized people can establish their right. It ensures

inclusion of marginalized poor in the road map of economic growth and development of a country. These activities ensure good governance.

2.7 Conceptual framework

In order to show correlation on the different dimensions of socio-economic development, some variables are identified and selected taking into consideration of economic, social, technological and environmental dimensions for sustainable development. To have a common framework that provides basic understanding of the relationship between the aspects of solar electrification and socio-economic development a conceptual framework is designed presented in following figure-3.

Figure-3: Conceptual analytical framework



CHAPTER THREE

METHODOLOGY

3.1 Introduction:

This study is designed to explore the socio-economic impacts of SHS in remote rural areas of Bangladesh. The study is based on primary data. Secondary sources are also used. Due to technology based social research a mixture of qualitative and quantitative methodological approaches are applied. General information regarding the SHS dissemination programme and socio-economic impacts of solar electricity are collected from secondary source and interviews with local experts. Primary data of the study are collected through an extensive household survey method using questionnaire. Secondary sources are also used to support the survey data. Questionnaire is designed as present and before SHS installation to measure role of SHS in socio-economic development of rural area.

3.2 Household survey:

To reveal quantitative as well as qualitative information from users of SHS, empirical household level data are collected through a household survey conducted in three villages. Overall, 90 interviews in rural households have been conducted by designed questionnaire. The questionnaire is designed based on selected variables of the study. The dependent and independent variables are selected for the purpose of the study shown by the following table-1

Table-1: Variables, Indicators, Operational definition and level of measurement

Dependent Variable	Indicators	Operational definition	Level of measurement
Socio-economic Development	Household total income	Total income from all sources in a household	Interval
	Educational status	Improvement in the quality of education	Interval & Dichotomous
	Quality life/Health status	Improvement of health	Interval & Dichotomous
	Access to information	Access to Radio, TV, mobile, internet etc	Interval

Independent Variable			
Type	Variable	Operational definitions	Level of measurement
Demographic	Age	Present age of respondent	Interval
	Family members	Dependent number of family member	Interval
	Marital status	Is the respondent married or not	Nominal
Economic	Household income	Average total income in a month of a household	Interval
	Energy expenditure	Total cost for lighting & other purposes	Interval
	Agricultural/Business production	Production increased in agriculture/business activities	Interval
	Entrepreneurship	Opportunity creation for business in rural area	Interval
	Employment	New opportunity for business/production	Dichotomous
	Working hours	Extended working time for production/business	Interval
Social	Educational benefit	Extended time for education and access to educational program	Interval
	Healthcare	Household environment with decreasing incidence of diseases and creation of better and more access to facilities for health benefits	Interval
	Socialisation	SHS decrease household workload, increase leisure time, entertainment and communication for quality life	Dichotomous & Interval
Technological	Attitude towards technology	Respondent is in favour or disfavour of using solar appliance for improving quality life	Interval
	Telecommunication	Communication with mobile phone, internet	Interval

		etc	
	Adaption	Respondent's satisfaction on SHS	Dichotomous
Environmental	Environment sustainability	Affordable, accessible & reliable energy that reduces environmental degradation with low carbon emission	Dichotomous

Questionnaire is the principal tool for data collection (Annexure-1). The questionnaire is characterised by the mixture of closed and open questions, allowing the collection of quantitative as well as information on before and after using SHS in the household. The questionnaire is structured as follows:

Demographic information: This part is designed to collected data on household head and spouse age, sex, marital status, education level including children and their educational status.

Socio-economic information: Major information is collected in this part. It is designed to collect data on economic situation, sources of energy for lighting and expenditures, productive activities in the household, entrepreneurship, employment, working hour, attitude and adaptation of SHS technology, environmental and social approaches of SHS.

As no baseline data is available, questionnaire is designed requesting respondent to provide all information for the present situation as well as before using of SHS. Data are collected in three villages where SHS dissemination occurred at the same time.

To identify SHS-villages for the household survey the following criterion are also applied:

1. Medium size of village (about 400-500 households),
2. Ongoing SHS dissemination for about five years,
3. Electricity from the national grid is not available,
4. Income level of households is about average (not especially poor or wealthy).

First of all, the study area is selected. It is located at Goffergoaw upazilla in Mymensign district, about 120 km north of Dhaka city and 40 km from Mymensign. With the help of local administration and NGOs staff engaged for Solar Home System dissemination (BRAC and Grameen Shakti) three villages are identified for the survey, namely Tangab (village A), Char kamaria (village B) and Sadua (village c)). Total 90 SHS-owned household data are collected from the villages. Households are selected randomly as there are many SHS-owned household in each of the villages.

For secondary sources of data journal, reports, working paper and documents regarding solar energy in Bangladesh have been consulted. Moreover, personal experiences and informal interview method are also used to have some more information about the issue. Data collection is conducted by author. Due to extensive questionnaire, the average duration of interviews was about 45 minutes and it is found interviewed household members showed keen interest in the survey activities. As rural people are lack of knowledge in English, the questions have been translated into Bengali for well understanding.

Following data collection, the questionnaires are entered into the Statistical Package for Social Sciences 15 (SPSS 15) and statistical analysis is performed. For income-related analysis, households are assigned into three income groups each roughly representing one third of the total number of households: low-income (below 8000 BDT/month), middle-income (8000-12000 BDT/month) and high-income (above 12000 BDT/month) households.

CHAPTER FOUR

DATA ANALYSIS, RESULTS AND DISCUSSIONS

4.1 Introduction:

Background, concept, policy and present situation of solar electrification dissemination for bringing socio-economic development in rural areas have been discussed. It is observed from the previous discussion that energy plays the key role for development. Due to rise of fuel price and increasing carbon emission worldwide, there is a global shift towards renewable energy like solar, wind etc. Being in tropical region, Bangladesh is a solar energy rich country. Solar energy can play a vital and secure energy source for sustainable development. The main objective of this study is to assess the impacts of solar energy on socio-economic development in rural areas of Bangladesh. To verify the objective empirically, a cross-section of 90 randomly selected households in three villages have been surveyed with a structured questionnaire. The survey results are analyzed as follows in the following sections.

4.2 An overview of sample villages:

As mention in methodology the survey is conducted in three villages. Village Tangaba (Village A) is the biggest of the surveyed villages with an estimated 1,596 households. Average household size is approximately 5 persons per household and the approximate population of the village is around 7,510. The households are compact and situated in open area covered by rice and vegetable fields. A primary school and local market are available. The next electric grid line is about 10km away from the village. SHS dissemination was started around six years ago.

Char Kamaria (Village B) is slightly smaller with about 3,416 inhabitants. The village constitutes approximately 683 households and average household size is approximately 5 persons per household. Households are scattered. There is also a school and local market. The grid line is about 15 km away from the village. More than 50% of

households are equipped with SHS and it dissemination was started more than five years ago.

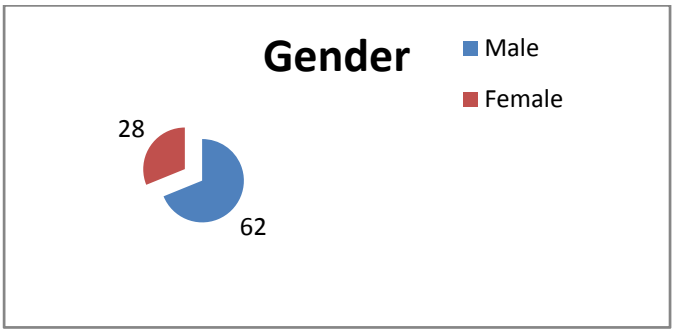
Sadhua (Village C) is smaller than the two other villages and constitutes approximately 458 households with about 2,252 inhabitants. This village is more compact than other two villages. Rice production and fish cultivation are prevalent around the village. A primary school and village market are also available in the village. SHS dissemination was started in the village around six years ago.

4.3 Household characteristics:

4.3.1 Demographic analysis of households:

A total of 90 respondents are interviewed for primary data collection in the survey. 70% household heads and 30% respective spouses participated in interview. During the survey men prefer to participate in interview than women. But, women also show their keen interest in answering the questions. So 68.89% male household members and 31.11% female household members are interviewed in the survey.

Graph-1: Gender of respondents

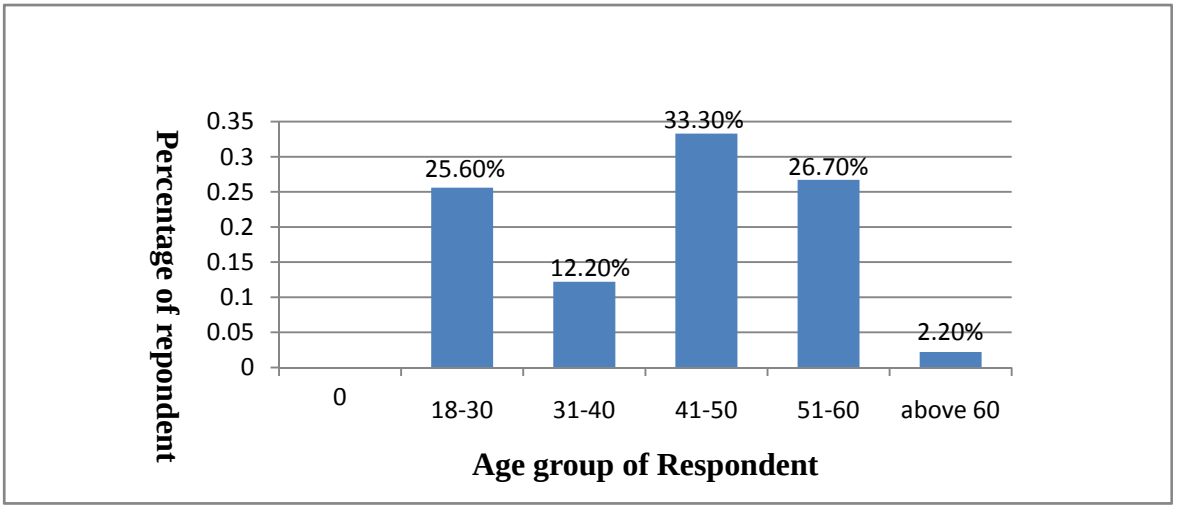


Data: Household survey

Graph-1 illustrates the frequency of gender distribution of sample where 62 respondents are male and 28 are females. Sometimes other household members or neighbours have also participated and showed keen interest in the survey.

Respondent's age is varied from 18 to 65. Graph-2 illustrates the percentage distribution of respondent age group. It indicates that respondents of 41-50 age group (33.3%) participate more than the others age group.

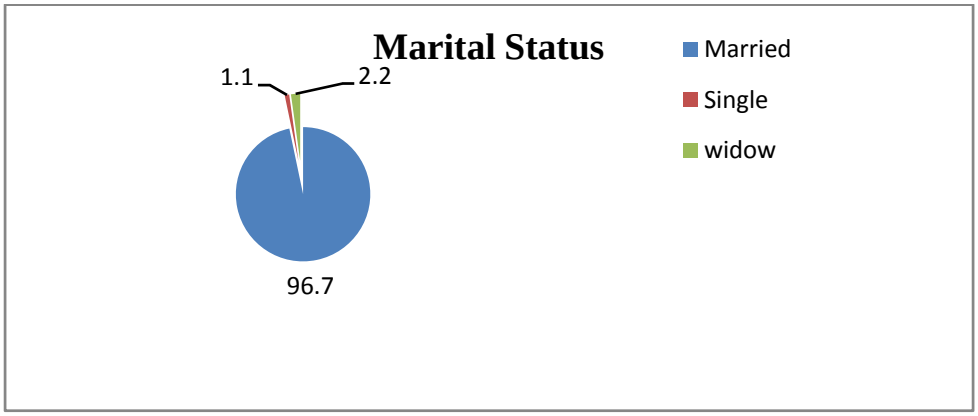
Graph-2: Respondent's age group.



Data: Household survey

In village, households are constituted with household head (mostly male), spouse, often with children and other family members, such as old father or mother or brothers living in the same household. Average size of household member is found 4.93 persons per household, which is nearly same, the country average for rural areas of 4.36 persons per household (*BANGLADESH POPULATION AND HOUSING CENSUS 2011: p xi*, Bangladesh Bureau of Statistics**)**. In case of marital status 96.7% of respondents are married. Graph-3 describes the marital status of household.

Graph-3: Marital status of respondents

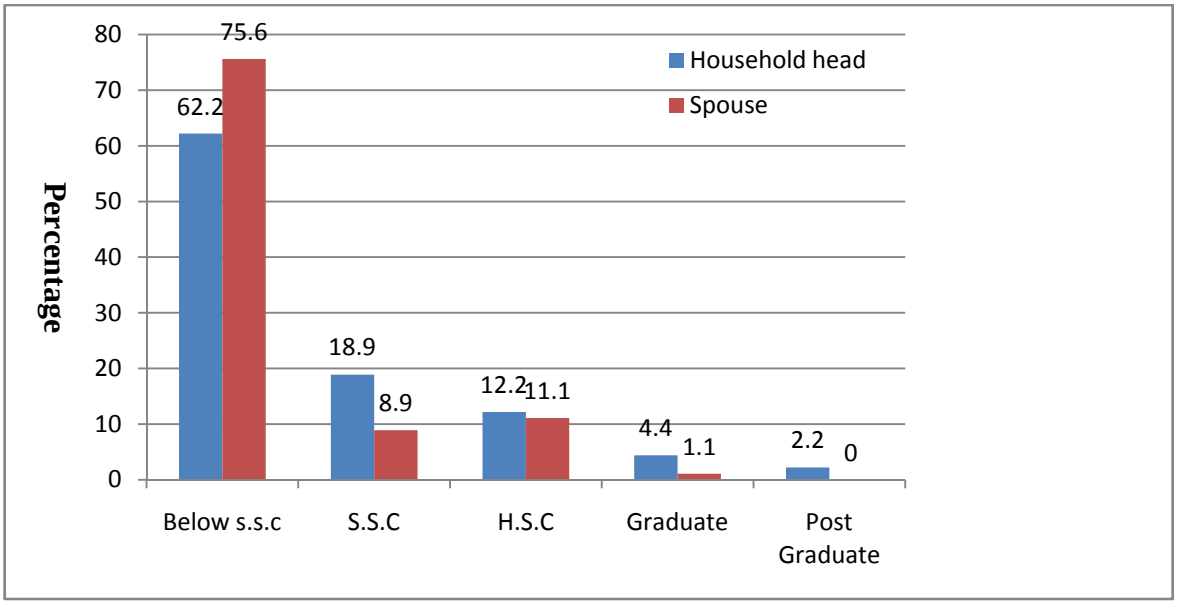


Data: Household survey

In the study, it is found that husband of the households are on an average ten years older than their wives which illustrates the traditional marriage age differentials in Bangladesh.

The level of education among the household male and female is very much striking. Graph-4 illustrates the educational status of male and female in the household. It represents that educational status of 62.2% (n=56) male and 75.6% (n=68) female are below S.S.C level while 18.9% (n=17) male and 8.9% (n=8) female are S.S.C passed. Male and female education status are near same at H.S.C level but female are very few at graduate level.

Graph-4: Educational status of household heads & spouses



Data: Household survey

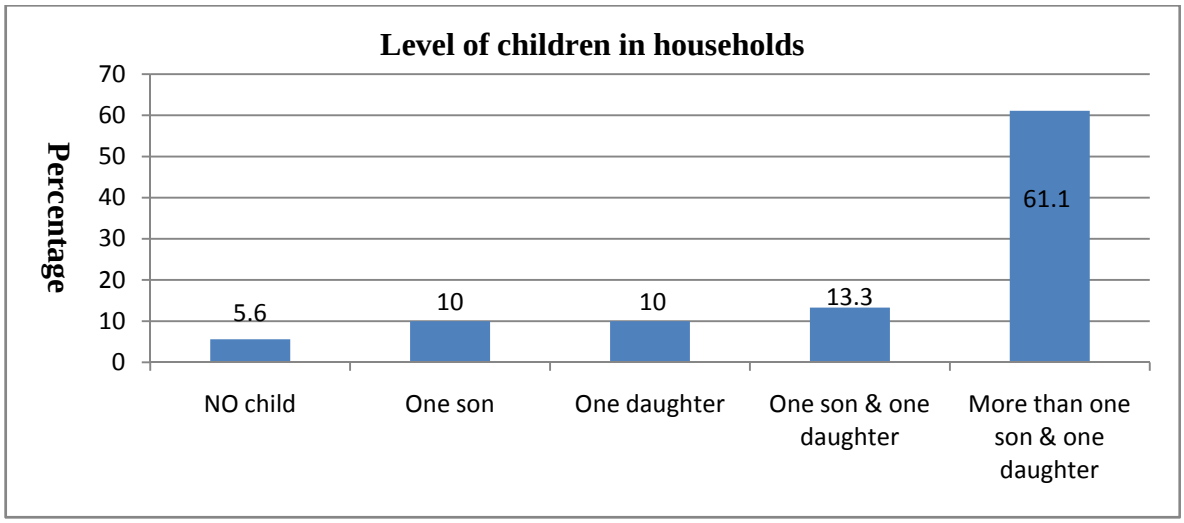
Average year of schooling for the household head and spouse is 6.74 years. Average year of schooling for male is 7.41 years while it is 6.08 years for female of the household.

4.3.2 Household children and their educational level:

The average number of children in the survey household is 2.58, which is slightly higher compared to national average household children of 2.3 (*Bangladesh Demography and Health Survey-2011*). The figure is high as the survey area is remote compare to

developed village in Bangladesh. Graph-5 represents the level of children in household. About 61% households endow more than one son and one daughter, while 5.6% households have no child.

Graph-5: Level of children in households



Data: Household survey

Children from 74.5% of households attend in educational institutions. Remaining 25.5% of the households are either having no children or no school going kids. The average number of children attending educational institutions is 1.22 per household. Table-2 illustrates the result. It reveals that high school going children are more than primary school going one.

Table-2: Children of the household and their level of education

Children	Percent	Institution	Percent
No child	5.6	Primary school	5.6
One son	10.0	High school/Madrasha	17.8
One daughter	10.0	Collage	6.7
One son & one daughter	13.3	University	2.2
More than one son and one daughter	61.1	Primary and High school	12.2
-	-	Primary, High school and collage	5.6
-	-	High school and collage	24.4
-	-	No schooling	25.5

Data: Household survey

4.4 Household economic situation:

4.4.1 Household occupation:

Agricultural farming is the main household occupation in the survey villages. Table-3 represents the household occupation. About 43.3% household heads occupation are farmer and 3.3% are labour. A significant part of household occupation is service and among them mojority are overseas employee and village based services like teacher, government employee, NGO worker etc. Occupation of other household males is skill worker, shopkeeper, agricultural goods trader, small business, rickshaw/van puller, vehicle driver etc. Conversely, household females are mainly engaged in household work. About 93% women are housewife, 4.5% are skill worker like handicraft making or sewing and 2.3% are service holder.

Table-3: Occupation of household head and spouse

Household head	Percent	Spouse	Percent
Farmer	43.3	Skill worker	4.5
Labour	3.3	Service	2.3
Skill worker	4.4	Housewife	93.01
Service	27.8		
Shopkeeper	5.6		
Business	3.3		
Rickshaw/van puller/Driver	8.9		
Others	2.2		

Data: Household survey

4.4.2 Household income and economic condition:

Household income of the survey villages mainly comes from agriculture, agriculture related work and small businesses. Crop cultivation, livestock, poultry and fish farming are main agricultural activities. The major agricultural crops are rice and vegetables. After agriculture foreign remittance (mainly from Middle-East and Malaysia) is the main source of income in many households of the villages. Other prevalent economic activities are trading agricultural goods, small business in village market and services like agriculture labour, rickshaw or van puller and workers of government and private organization at village level. Adult males of the households are the main earning persons. Women are engaged in household related work. In few cases women are

engaged in handicraft production or services. But most of the low income household males are day labourer.

In survey, estimated present average monthly total income of the households is 9333 BDT and before installing SHS it was about 7866 BDT which is nearly same as the average household income 9648 BDT for the whole of rural Bangladesh (*Household Income and Expenditure Survey 2010, Bangladesh Bureau of statistics)***.** From average income it is found that the villages are neither wealthy nor extreme poor. The following table-4 represents the household monthly total income in the villages before and after installation of SHS.

Table-4: Household total income before and after installation of SHS

Present household total income		Household total income before installing SHS	
Household total Income (BDT/month)	Percent	Household total Income (BDT/month)	Percent
4000- 6000	11.1	4000-6000	14.4
6001-8000	16.7	6000-8000	27.8
8001-10000	30.0	8001-10000	33.3
10001-12000	31.1	10001-12000	21.1
12001-14000	8.9	12001-14000	3.3
Above 14000	2.2	Above 14000	-

Data: Household survey

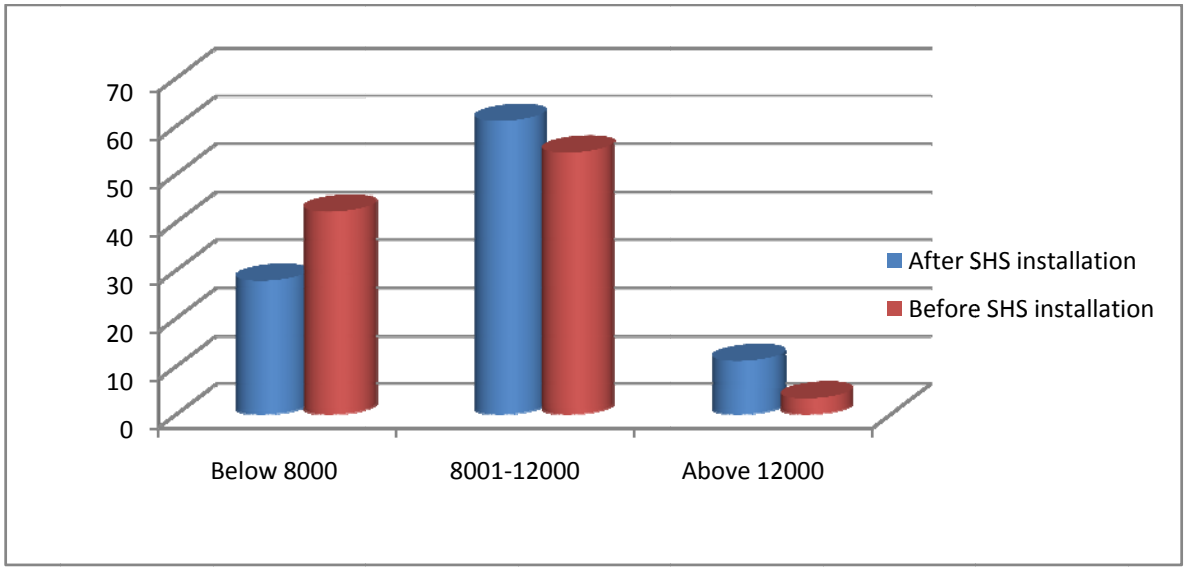
Income of the households is dispersing from 4000 BDT to above 14000 BDT. Nearly 11.1% household income is below 6000 BDT and about 2.2% household income is above 14000 BDT. For better understanding the distribution of income has been grouped as lower income group (below 8000 BDT), middle income group (8000-12000 BDT) and higher income group (above 12000 BDT). The following table-5 and Graph-6 represent distribution of household income group before and after installing SHS.

Table-5: Distribution of household total income before and after installation of SHS

Present household income		Household income before installing SHS	
Household income group (BDT/month)	Percent	Household income group (BDT/month)	Percent
Below 8000	27.8	Below 8000	42.2
8001-12000	61.1	8001-12000	54.5
Above 12000	11.1	Above 12000	3.3

Data: Household survey

Graph-6: Distribution of households by income groups



Data: Household survey

Before installation of SHS (5 years ago) about 54.5% household monthly total income was between 8000-12000 BDT. 42.2% household income was below 8000 BDT and 3.3% household income was above 12000 BDT. After installation of SHS middle income group increases from 54.5% to 61.1% while higher income group increases from 3.3% to 11.1%. On the contrary, lower income group decreases to 27.8% from 42.2%. Mathematically it is obvious that 34.12% households of lower income group shift their household income from lower to middle income group and 12.11% middle income group shift their household income from middle to higher income group.

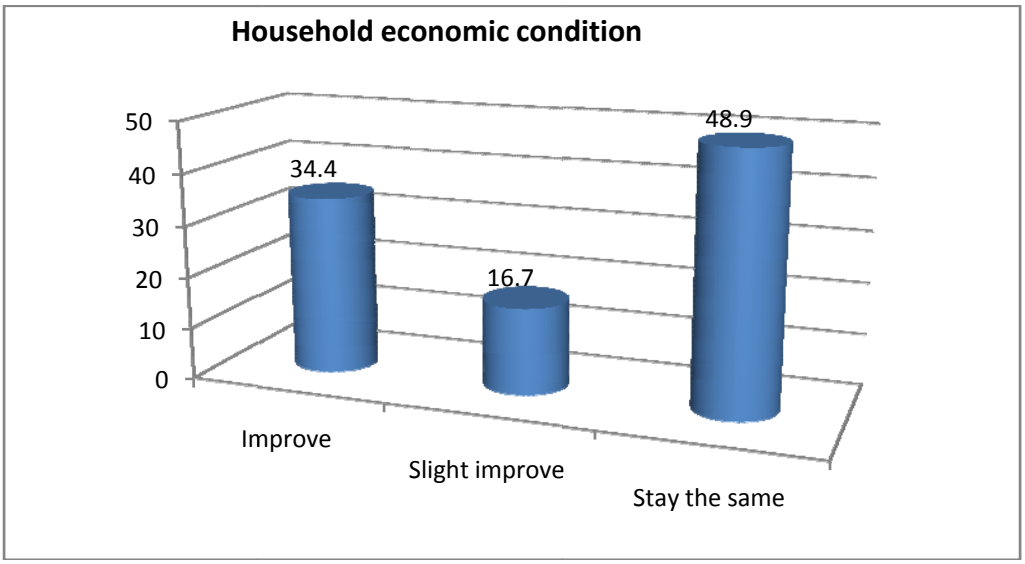
When the respondents are asked to state the household economic condition before and after installing SHS, 34.4% households state that household economic condition has been increased. About 16.7% household state economic condition is slightly increased while 48.9% household state economic condition remained the same. Table-6 and Graph-7 illustrate the result of household economic condition after installing SHS.

Table-6: Household economic condition after installation SHS

Household economic Condition	Percent
Improve	34.4
slight improve	16.7
stay the same	48.9

Data: Household survey

Graph-7: Household economic condition after installation SHS



Data: Household survey

Comparing the improve economic condition with household income group it is found that economic condition has been increased highest for the higher income group of households (90%), moderate for middle-income households (36.36%), and extremely weak for the lower income group of households (8 %). Table-7 and Graph-8 shows the comparison between respondent household total incomes with household economic condition.

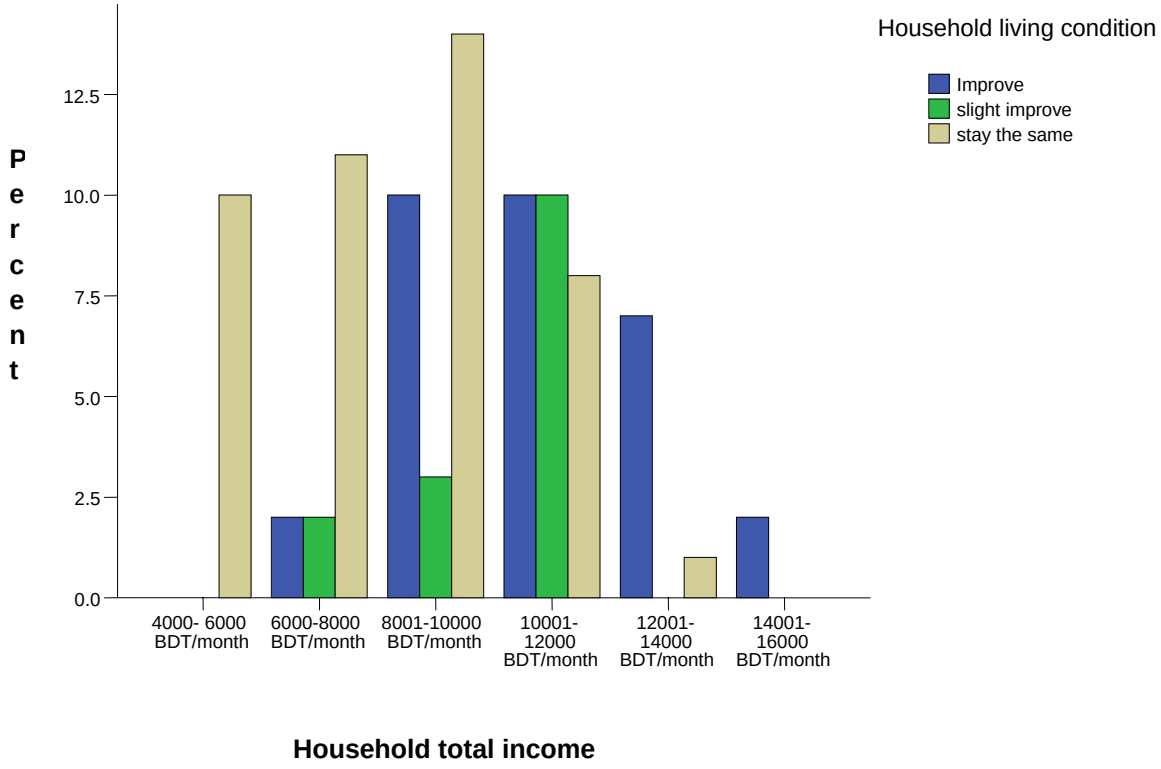
Table-7: Household total income and household economic condition

Household total income (BDT/month)	Household economic condition			Total
	Improve	slight improve	stay the same	
4000- 6000	0	0	10	10
6000-8000	2	2	11	15
8001-10000	10	3	14	27
10001-12000	10	10	8	28
12001-14000	7	0	1	8
14001-16000	2	0	0	2

Data: Household survey

It indicates that economic condition has been improved mostly for the higher income group household in the villages. The lower income group households are unable to increase their economic condition after installation of SHS.

Graph-8: Household total income and household economic condition



4.5 Household lighting sources and expenditure

Before installation of SHS, kerosene was the most prevalent source of household lighting in survey area though both candle and kerosene were also used in few cases. Table-8 describes the result of energy sources used for lighting and expenditure before SHS installation. Normally, kerosene was purchased from the local market and average monthly expenditure was about 228 BDT/month. The figure is significantly lower comparing with recent price of kerosene. As the price of kerosene has been increased the expenditure is also increased in accordance day by day.

Table-8: Energy sources used for lighting and expenditure before SHS installation

Source	Percent	Cost range (BDT/month)	Percent
Kerosene	84.4	100-150	11.1
Both Kerosene & candle	15.6	151-200	25.6
-	-	201-250	27.8
-	-	251-300	21.1
-	-	300-350	7.8
-	-	above 350	6.7

Data: Household survey

At present, households in surveyed village use the decentralized electricity from SHS and diesel run generator. Many NGOs are active for SHS dissemination under the IDCOL programme in the villages. Among them Grameen Shakti and BRAC are leading NGOs for SHS dissemination. Nearly 13.3% SHS have been purchased paying the whole amount of money by cash managed from household income and the rest have been purchased using micro-credit options offered by NGOs. In case of micro-credit scheme, it is necessary to sign a financing contract of installment lasting for 24-36 months. When life of the loan is only 24 months the monthly installment is higher in accordance. Table-9 represents the purchasing mode of SHS in the survey villages.

Table-9: Purchasing mode of SHS.

Mode of purchasing SHS	Percent	Month of installment	Percent
Installment	86.7	36 month	89.74
Pay whole amount of money	13.3	24 month	10.26

Data: Household survey

Previous study identified household lighting expenditure save money due to switching from traditional source of light to electricity. Some expert also identify that installation of SHS is economically benefit for household in Bangladesh. To find out expenditure for lighting in the household information are collected in survey. After installing SHS cost of lighting for household is the monthly installment and maintenance cost of the system. After paying an initial down payment between 2,000 to 12,000 BDT (average 5698 BDT), the households paid monthly installments ranging from 200 to 1,200 BDT

(average 807 BDT). Table-10 represents the down payment and installment for purchasing SHS in the household.

Table-10: Down payment and installment for purchasing SHS

Down payment (BDT)	Percent	Installment per month (BDT)	Percent
2000-3000	10.28	200-400	12.81
3001-4000	15.35	401-600	5.08
4001-5000	24.36	601-800	28.17
5001-6000	10.28	801-1000	23.09
6001-7000	11.54	1001-1200	30.83
7001-8000	12.81	-	-
8001-9000	1.38	-	-
9001-10000	10.28	-	-
11001-12000	3.81	-	-

Data: Household survey

In survey, it is seen that purchasing of SHS for the households through micro-credit scheme is affordable, as very few households state that down payment and monthly installments is financial burden for them. After installation of SHS maintenance cost is very low as PO provides 20 years free service for the system and 5 years for the battery. During this period expenditure is only for charging battery and changing bulb of the system. Maintenance cost and period of using SHS are also collected from the household survey. Table-11 represents the data of maintenance cost for SHS and period of using the system.

Table-11: Maintenance cost and period of using SHS

Maintenance cost (BDT/month)	Percent	Period of using SHS (years)	Percent
0-5	27.8	below 4	8.9
6-10	48.9	4-6	77.8
11-15	16.7	above 6	13.3
16-20	6.7	-	-

Data: Household survey

Maintenance cost range from 0 to 20 BDT (average 7.98 BDT) per month and the period of using SHS range from below 4 year to 8 years. About 8.9% households have been using SHS for less than four years, 77.8% households for 4-6 years and rest 13.3%

households have been using the system for more than 6 years. Battery of the system ends to its life span after five years. But many of the batteries are still using after its life span. In the survey, it is identified that about 13.3% households are using the system without changing it. It is also found that more than 90% households never need to use kerosene or other source of energy for lighting after installation of SHS. On an average 90% kerosene consumption is replaced by installing SHS.

4.6: Household solar electricity consuming activities:

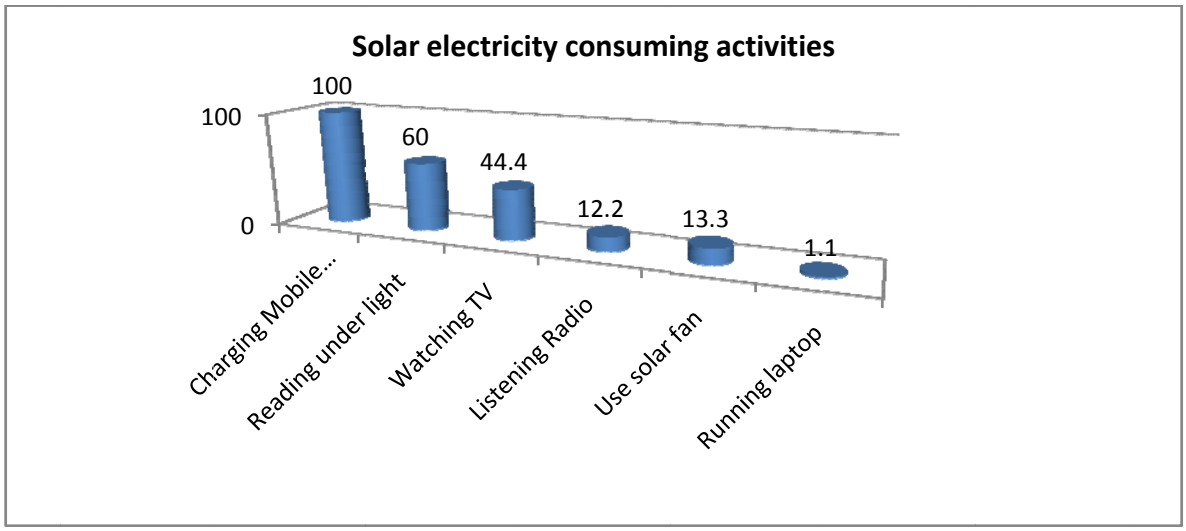
All households use solar tube lights for illumination of their houses & mobile phone chargers to charge mobile phones. Nearly 60% households use SHS for reading purpose. More than 44% households use solar electricity for watching TV and about 12% of households use solar electricity for listening radio. Study also reveals that 13.3% households use solar electricity for running solar fans and only one person uses solar electricity for running a laptop. Using solar fan is very limited due to high consumption of electricity. Besides, households cannot use fridge for low average capacity of SHS. Table-12 and Graph-9 show the distribution of the use of solar electricity consuming activities in households.

Table-12: SHS electricity consuming activities in household

Activities	Percent	Cumulative Percent
Charging of mobile phone	30.0	30.0
Watching TV and Charging mobile phone	10.0	40.0
Watching TV, Reading under light and charging mobile	21.1	61.1
Watching TV, Listening radio, Reading under light, use solar fan and charging mobile	12.2	73.3
Watching TV, Reading under light, Charging mobile phone, Use solar fan and laptop	1.1	74.4
Reading under light and Charging mobile phone	25.6	100.0

Data: Household survey

Graph-9: Distribution of the use of solar electricity consuming activities in households



The most important electricity consumption activities in SHS owned households are reading, conducting household work under clear light and charging mobile phone. It is found that for available network and user friendly communication every households use mobile phone. Watching TV and listening radio are also important electricity consuming activities. In some cases household head or spouse runs grocery in their household. They use SHS for lighting and running TV which increases selling in the shop. The following figure-4 shows the appliance used in household.

Figure-4: SHS appliances: tube light and TV in a shop and household

Photographs: Household survey

Traditionally, kerosene was the most important applications of energy for lighting in rural households of Bangladesh. Due to increase affordability to buy SHS applications of solar electricity for entertainment and access to information through radio, TV and mobile phone, use fan in hot summer, charging battery of mobile phones and laptop have emerged in the rural households.

4.7: Household attitude towards SHS electricity and technology for socio-economic development:

Every households desires electricity as it facilitates quality life in rural area. Due to unavailable grid line electricity, SHS users are satisfied with the system. Nearly 80% household member expresses their satisfaction and 20% household member expresses their dissatisfaction with the present system. Table-13 illustrates the survey result.

Table-13: Satisfaction with the use of SHS

Attitude of households	Percent
Highly dissatisfied	8.9
Dissatisfied	11.1
Satisfied	16.7
Moderately satisfied	26.7
highly satisfied	36.7

Data: Household survey

Dissatisfactions are for inadequate management from respective NGO, low power of SHS and low capacity during cloudy day. But the most positive side of SHS electricity use is self-ownership and uninterrupted supply of power. Besides, households prefer SHS for its reliable and continuous electric supply in contrast to grid-related problems like power cuts and load shedding practices. Safe technology is another factor for liking SHS in households. Many studies also mention these factors are important for household attitude towards solar electricity. In order to find out attitude towards solar technology households are asked as “Are TV, Radio and mobile phone beneficial for socio-economic development”. Table-14 shows the opinions of the households.

Table-14: TV, radio and mobile phone beneficial for socio-economic development.

Technological attitude of SHS households	TV	Radio	Mobile
	Percent	Percent	Percent
Disagree	21.1	26.7	00.00
Neutral	14.4	20.0	00.00
Agree	47.8	46.7	35.6
Strongly agree	16.7	6.7	64.4

Data: Household survey

All of the households state that mobile phone is most beneficial for socio-economic development. Nearly 64.5% households agree that TV is beneficial for development, 14.4% households are neutral and 21.1% households disagree with the opinion. In case of Radio, 53.4% households agree, 20.0% households are neutral, and 26.7% disagree that radio is beneficial for socio-economic development in rural area.

4.8 Socio-economic impacts of SHS

In order to find out socio-economic impacts of SHS the questionnaire is designed to request respondents about the changes in their daily life that have been occurred after installing the Solar Home Systems. About 98.9% households state that SHS has brought changes in their daily life. Table-15 represents the respondents answer.

Table-15: Changes in daily life of household after installing SHS

Are there any changes in daily life after installing SHS?	Percent
Yes	98.9
No	1.1
Total	100.0

Data: Household survey

When the respondents are asked to state what extent the changes in their daily life, their answers are summarized in table-16.

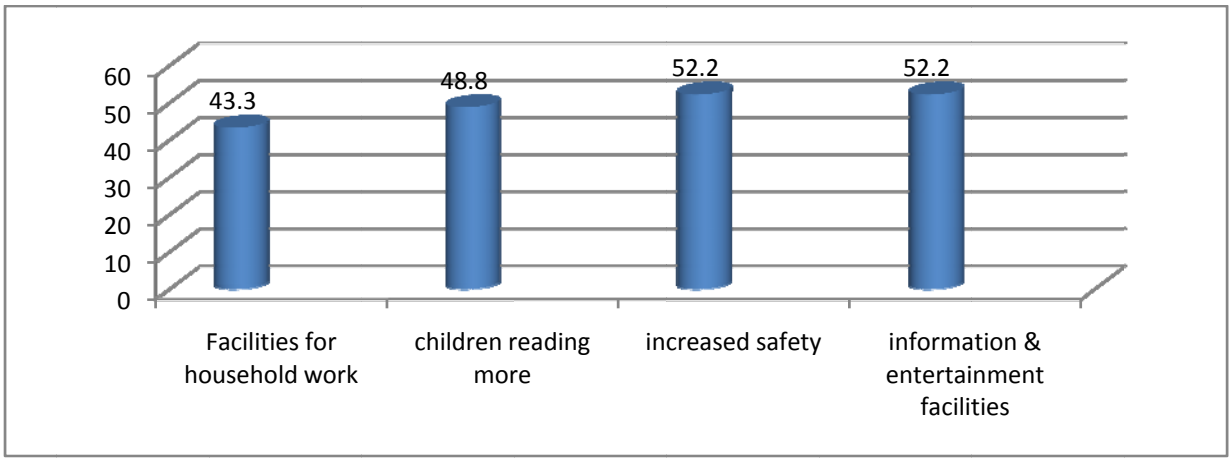
Table-16: Kinds of change in daily life of household members

Kinds changes in daily life of household members	Percent
Children reading more	4.4
Increase safety and information & entertainment facilities	7.8
Increased facility for household work	43.3
Increase safety, Children reading more and increase information & entertainment facilities.	21.1
Children reading more, increase information & entertainment facilities and increase safety	23.3

Data: Household survey

Increase safety, access to information & entertainment facilities are perceived the most important changes by 52.2% of the households. Clear household lighting has increased the children more reading is quoted by 48.8% of the households. Household Lighting from SHS has increased facilities household work is also an observable change has been expressed 43.3% of the households. Other frequently mentioned changes are improved household environment, increase people respect and decreased stealing. Graph-10 represents the result of the survey about what are the changes in daily life after installing SHS in households.

Graph-10: Kinds of change in daily life after installing the SHS in household



Data: Household survey

The following sections describe in detail of the changes occurred in the households and the impacts of solar lighting that are mentioned by respondent during survey of the households.

4.8.1 Household income and productive use of SHS

The correlation of household income with rural electrification is a debating issue. Previous study mentioned as "Providing electricity for meeting lighting needs of households and rural markets can yield positive results, including improvements in quality of life and increasing income and employment opportunities" (*Faisal Ahammed et al, 2008:102***)**. Solar PV technology program in remote, rural & off grid villages has a tremendous impact especially on women and children. Women can enjoy hassle free lightening and earn extra money by sewing or poultry farming utilizing their extended evening time. Women can involve in repair, maintenance and sale of solar accessories. It makes decent jobs for women right in their villages (*Khalid Md. Bahauddin, et al, 2010: 104)*. Previous studies emphasised on SHS impacts on rural business. They frequently mentioned that SHS increase working hour, attract customer for improved light, improved productivity for fresh air and clear light. The study also mentioned the potential of SHS in income generating activities for clear & fresh light at night like rice husking, poultry farm, solar pump for irrigation or cottage industries (sewing, handicraft production). The research identified that illumination of poultry farms increased productivity: in the evening, chicken reduced food intake and the amount of laid eggs if kept in darkness. Moreover, the study also mentioned extended time in evening increased income in small business and shops at village market. But there is very limited qualitative data on the impact of SHS especially on household income and productivity. To find out impacts of SHS on household income generation activities questionnaire is designed to state on production–related information before and after installation of SHS. Table-17 and table-18 illustrate the information of household income generation before and after SHS installation.

Table-17: Income generating activity in the household

Before SHS installation	Percent	After SHS installation	Percent
Yes	1.1	Yes	8.91
No	98.9	No	91.1

Data: Household survey

Table-18: Income generating activities and average income before and after installation of SHS

After installing SHS	Percent	Average income (BDT/month)	Before installing SHS	Percent	Average income (BDT/month)
Husking rice	1.1	8500-10000	Husking rice	1.1	5501-7000
sewing cloth	1.1	1000-2500	-	-	-
Making handicraft	3.3	2501-4000	-	-	-
Poultry	1.1	8500-10000	-	-	-
Small business/shop keeping	2.2	8500-10000	-	-	-

Data: Household survey

Respondents are asked to mention whether there is/was any income generating activity in the household and if yes what is/was the activity. Only 8.9% respondents answer positively. SHS provides small loaded light. The load is too small to use a productive appliance or machinery. Besides, most income generating activities in village is done during day time. So, only 8.9% (n=8) households have income generating activities. Before installing SHS only one household has income generating activities. But after installation of SHS the number increases to eight. In the study, observable income generating activities under solar electricity are sewing cloth, poultry farming, husking rice mill and running small shop and average additional income is 3000 BDT form running husking rice mill, running small business shop and poultry farming, 1000-2500 BDT form sewing cloth and 2500-4000 BDT form handicraft production. It is found that overall income generating activities in the household are limited and additional income from the activities is also low. Generally, household head and spouse are engaged for income generating activities in day time. Though the evening time extended

for installation of SHS, high-income household heads have been engaged themselves for entertainment or socialization with neighbors, friends or relatives and the spouses have been engaged with their children's studying and household work under solar electricity. Besides, it has also been observed that high income household heads discourage their spouse to engage in income generating activities, like handicraft production or sewing. On the other hand, low-income households heads or spouse are unable to utilize the extended times due to lack of proper training for income generating activities and lack of marketing knowledge.

4.8.2 Entrepreneurship and Employment:

Entrepreneurship and Employment are two important factors for socio-economic development. Very limited study is conducted for entrepreneurship and employment generation for rural electrification. It is mention earlier that people are harnessing solar electricity to run small businesses**.** With solar power people can operate a rice-grinding mill, poultry farm in rural area. SHS also creates business as manufactures, wholesale suppliers, retail sale business, service business such as system design, system installation, consulting service etc. Many organizations have been engaged for assembling, repairing of solar accessories in rural areas, creating green jobs for rural people. In order to search the SHS impacts on entrepreneurship and employment generation in rural area, respondents are requested to state their experiences on creation of entrepreneurship and employment by SHS. Table-19 represents the answer of the respondents.

Table-19: SHS creates entrepreneurship and employment

Does installation of SHS creates entrepreneurship?	Percent	Does installation of SHS creates employment?	Percent
Yes	38.9	Yes	37.8
No	28.9	No	51.1
No comments	32.2	No comments	11.1

Data: Household survey

Nearly 38% respondents answer that SHS creates entrepreneurship and employment in rural area. When the respondents are asked on what level does the SHS create

entrepreneurship, 34.4% respondents' answers are average and 4.4% respondents' answers are more than average. Table-20 illustrates the respondents answer.

Table-20: Level of entrepreneurship

Level of entrepreneurship	Percent
Average	34.4
More than average	4.4
Missing	61.1

Data: Household survey

In case of employment opportunity creation by SHS respondents opinion that small business in household, handicraft making, sewing cloth, rearing poultry, processing homemade product etc are available opportunity sectors in remote rural areas. The following table-21 illustrates the opinions of respondents.

Table-21: Employment opportunity sectors create by SHS

Employment sectors	Percent
Agricultural products	1.1
Small Business	12.2
making handicraft	13.3
Sewing cloth	6.7
Poultry	1.1
Making handicraft and sewing cloth	2.2
Small business, Making handicraft and Sewing cloth	1.1
Missing	62.2
Total	100.0

Data: Household survey

It is found that SHS are using mainly for household lighting, running TV and mobile phone. Installation of SHS in the rural areas can facilitate an opportunity for the villagers to open up small businesses like mobile phone charging shops, computer training centres, TV halls, solar refrigeration centre, solar irrigation system etc. But most of the respondents are unaware of new technology of solar electricity.

4.8.3: Working hour of household members before and after SHS installation

Working hour influences the economic development directly. But human behaviour, society concept, culture and environment affect on working hour. There are very limited studies about the working hour of household on Bangladesh perspective. To find out impacts of SHS on household working hour information of household member working duration are collected before and after installation of SHS. Table-22 summarizes the information of household women, men and children working hour before and after installation of SHS.

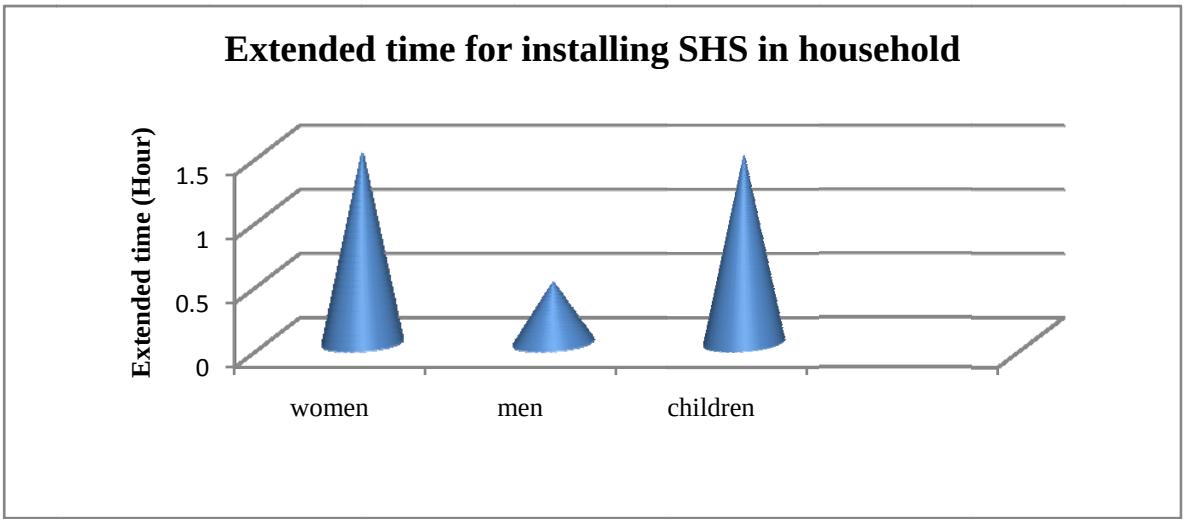
Table-22: Working hour of household women, men and Children before and after installation of SHS

	Women		Men		Children	
After installations of SHS	Working hours (hour/day)	Percent	Working hours (hour/day)	Percent	Working hours (hour/day)	Percent
	4-6	6.7	4-6	10.11	4-6	12.85
	6-8	25.6	6-8	52.78	6-8	87.14
	8-10	67.8	8-10	37.10	-	-
Before installations of SHS	4-6	17.8	4-6	10.11	4-6	85.73
	6-8	77.8	6-8	76.44	6-8	14.26
	8-10	4.4	8-10	13.44	-	-

Data: Household survey

Before installation of SHS, average working hour of household women was 6.73 hours. After installation SHS, household working hour increases to 8.22 hours. Household women working hour extends 1.49 hours after installation of SHS. But average working hour of household men was 7.06 hours and it become 7.53 hours after installation SHS. Household men working hour extends about 0.47 hour (29 minute). On the contrary, household children working hour before and after installation of SHS is 5.28 hours and 6.74 hours respectively. Average extended working time for children is 1.46 hours. Graph-11 represents the extended working time for women, men and children after installing SHS in the survey household.

Graph-11: Time extended for household women, men & children after using SHS



Data: Household survey

4.8.4 Use of extended workable time and beneficiaries

Solar lighting in the evening increases the length of workable time for household members. Applications of solar electricity in mechanical water pumping, motorized milling machines for grinding grain can reduce household work load and thereby increase time for other productive works or recreations. To collect data on using the extended working time respondents are asked to provide information of using evening time before & after installation of SHS in the household. Table-23a, 23b and 23c represent the activities in the evening performed by household women, men and children before and after installing SHS respectively.

In village, majority women are housewife and basically stay at home. In evening time they are busy for household related work. Before installation of SHS 73.3% household women were engaged in household work, 17.8% in socialization with relatives and neighbours and 8.9% spent time by sleeping. But installation of SHS the household women get more time to engage in household related works, watching TV, productive work and reading.

Table-23a: Time spent by household women in the evening before and after installing SHS

Activities perform after installing SHS	Percent	Activities perform before installing SHS	Percent
Household work	50.0	Household work	73.3
Productive work	1.1	Socialization	17.8
Watch TV	3.3	Sleeping	8.9
Socialization	4.4	-	-
Household work and watching TV	20.0	-	-
Household work, Watching TV and Socialization	4.4	-	-
Household work and Socialization	11.1	-	-
Household work, Reading and socialization	5.6	-	-

Data: Household survey

Before installation of SHS about 50% household men were engaged in household work. But after SHS installation 50% household men engage in household work, watching TV and socialization with relatives and neighbours. Nearly 46.7% household men were involved only in socialization but after SHS installation those household men are involved in productive work and watching TV, listening radio etc. Before SHS installation 5.5% household men were engaged in sleeping, but after installation those household men engage in household work or some sorts of learning or entertainment activities.

Table-23b: Time spent by household men in the evening before and after installing SHS

Activities perform after installing SHS	Percent	Activities perform before installing SHS	Percent
Household work	18.9	Household work	46.7
Productive work	3.3	Reading/studying	1.1
watch TV	4.4	Socialization	43.3
Listening radio	3.3	sleeping	5.5
Socialization	4.4	Household work and Socialization	3.3
Household work and watching TV	3.3	-	-
Household work, watching TV and socialization	5.6	-	-
Household work and Socialization	30.0	-	-
Household work, Reading and socialization	26.7	-	-

Data: Household survey

An observable change occurs among the children in SHS installation households. Before installation SHS 23.4% household children read in the evening, 6% households children spent time on playing and 70% household children spent time by sleeping. After installation of SHS in the household 53.8% household children engage themselves in reading and studying. Besides, 33% household children engage in watching TV and reading books and 13.2% household children engage in some sorts of playing or entertainment in the extended evening time.

Table-23c: Time spent by children in the evening before and after installation of SHS

Activities perform after installing SHS	Percent	Activities perform after installing SHS	Percent
Reading/ studying	53.8	Reading/ studying	23.4
Playing	13.2	Playing	6.6
Watching TV and Reading	33.0	Sleeping	70.0

Data: Household survey

Comparing evening time activities in the surveyed households, it is found that after installation of SHS evening time become extend and therewith overall extended time

available for different activities for all members in the household. Access to solar electricity significantly extends the evening time and reduces the time required for household works. Though watching TV, listening radio or studying and playing are not direct productive work but these activities improve quality life in rural area, which are valuable for socio-economic development.

Beneficiaries

Women are often stated more beneficiary group, as they engage mostly household related work. Use of solar-electric appliance, clear light and fresh air for SHS provide more improve household condition for women. Moreover TV and radio program on women's education, women's empowerment, health and sanitation aware household women. To find out the more beneficiary in household survey respondents are requested to state the most beneficiary of SHS. Table-24 illustrates the result of the survey.

Table-24: The most beneficiary of SHS.

Who is the most beneficiary of SHS?	Percent
Women	20.0
Children	23.3
Women & children	32.3
Men, women & children	24.4

Data: Household survey

About 24.4% households state that women, men and children are equally benefited. Nearly 32.3% household state women and children, 23.3% households state children alone and 20% households state women alone are most benefited from SHS. However, from the household survey data it is found that children (80.0%) are the main beneficiary then women (76.7%) followed by men (24.4%). The children are benefited most for improved light and fresh air for reading and studying. They also get facilities of learning through TV, radio & mobile phone and also get rid of kerosene related hazard. Women are also benefited more as they get improve light for household work.

4.8.5 Education

Electric lighting in households generally improves household condition for education. Many SHS experts pointed out the possibility of school going children to study under electric lights in the evening to be a very important issue. Carbon less clear light encourages children to engage in more studying. Many studies in this line became consensus in this issue. Table-25 provides the result of the study which reveals a higher consensus with this issue and expresses an increase quality of reading and studying.

Table-25: SHS makes easy & extended time for reading

Does SHS make easy and extended time for reading?	Percent
Disagree	2.2
Neutral	25.6
Agree	50.0
Strongly agree	22.2

Data: Household survey

About 72.2% households agree that SHS makes easy and extended time for reading. Reading under kerosene light creates straining on the eyes. But solar electricity improves the household condition in remote rural area for quality education. The survey confirms that carbon less clear light motivate rural children to engage more time in reading and studying. Children in SHS households get the benefit of improved light and extended time for reading and studying, which dragging the under privileged children in electricity less area to the main stream of development and aggravating to reach in sustainable development.

4.8.6 Health

Like educational impacts solar electricity also improved household condition for quality health. Health-related issues can be considered from the household point of view as well as from the rural health institutions. In household level, SHS sustain fresh indoor air due to lack of carbon and smoke free light. At the same time health related awareness

program form TV and radio has an impact in household level. Rural Health Centres (RHCs) in Bangladesh are not effective due to lack of electricity. Solar electricity in RHC facilitates to use refrigeration and other medical equipment. Previous studies mentioned the benefits of solar electricity in rural health centre for using vaccine refrigeration, nebulisers, centrifuges machine, steriliser, water treatment equipment, emergency care at night and telecommunication. A study conducted by H U Chowdhury found that 'solar electricity created people awareness of health care and family planning through EPI programme. Providing electricity at community clinic improved the access to quality of healthcare, access to medicines, presence of doctor(s)/health worker(s), and safety in and outside the home' (H U Chowdhury, 2006). Some experts also argued in favour of SHS impacts on health at household level for smoke less lighting enabling improved treatment of patients at night and escape from kerosene related accidents. Respondents in the present survey also express that SHS improves the indoor air quality. They point out that kerosene lamps create smoke, which increase the incident of respiratory and eye diseases. Table-26 represents respondent agreement on SHS decreases incidence of diseases.

Table-26: SHS decreases the incidence of diseases.

Does SHS decrease the incidence of diseases?	Percent
Neutral	10.0
Agree	52.2
Strongly agree	37.8

Data: Household survey

In the survey 90% households express that SHS decrease the incidence of diseases. Members of the survey households also state that health related program on TV and radio increase their knowledge base on health and sanitation. Besides, mobile messages on vaccination program helps them to take necessary action on due time.

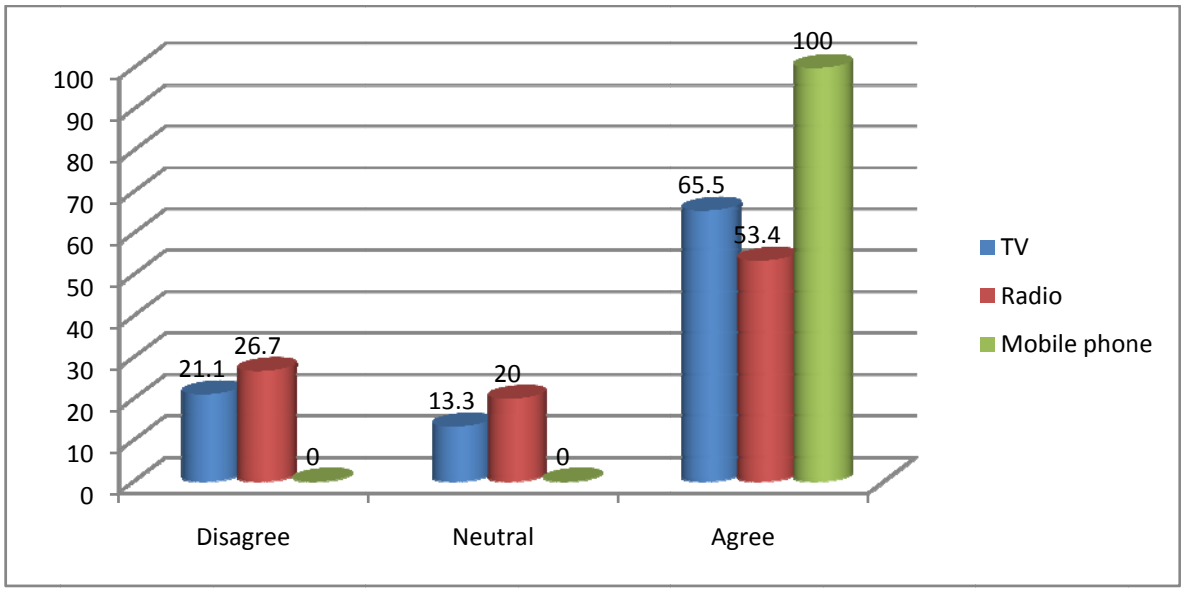
Fresh indoor air, regular health related awareness program in TV & Radio, health concern mobile message and reduce accident from kerosene lamps are important factors which improve health and sanitation of SHS-households member on a long-term basis.

4.8.7 Information and entertainment

Availability of access to information and entertainment program are important factors that provide overall quality of life in rural village. SHS provides facilities to get information and entertainment through using TV, Radio and mobile phone. As maximum SHS power is between 50 to 90Wp, use of black and white television sets is very much common in SHS-household. Previous studies also identified the use of TV and Radio is the most available application in the solar electricity. The applications of SHS have been drastically increase recently in rural areas of Bangladesh. Most of the applications are to meet the basic purposes of lighting and entertainment by operating TV and Radio in the household of rural areas. Watching television by using SHS develops the learning about several aspects of life and technology (*Mondal M. A. H., 2005, p.35*).

People in the rural household get market reports and information about market prices of agricultural product through TV and radio news and programs or mobile message. TV and radio provide adult education program, health and sanitation programme, agro-based technology which are important factors for positive impact of rural adult. Many SHS expert from national and international level also pointed out on using TV and radio program increase the social awareness as well as use of modern technology on education, health and agriculture. In the study all the beneficial factors are also identified and majority of the households agree with the SHS expert opinions. Graph-12 represents the household survey report on using TV, Radio & mobile phone.

Graph-12: Role of TV, Radio & Mobile phone for Socio-economic development



Data: Household survey

All the survey households agree that mobile phone is the most beneficial for socio-economic development. More than 65% households also agree that TV is beneficial for socio-economic development but 53.4% households agree for radio. Most of the respondents think that TV, Radio and mobile provide national and international news, which is very important for them. When the respondents are requested to state whether SHS creates facilities for entertainment, about 61.1% households agree with the statement. Table-27 expresses the household opinion on entertainment facilities by SHS in the survey.

Table-27: SHS creates facilities for entertainment

Dose SHS create facilities for entertainment?	Percent
Disagree	13.3
Neutral	25.6
Agree	46.7
Strongly agree	14.4

Data: Household survey

Respondents frequently mention that before installing SHS they usually spent time by sleeping or gossiping but after installation of SHS they watch health and education related TV program as well as Movies and drama. Though TV and radio are beneficial

for development 13.3% households disagree with the statement. They point out that children are more prone to TV serials than educational program. Sometimes families from neighbouring also create annoying in watching TV program. In spite of this, extended evening time for using SHS is much more beneficial than the period of before SHS installation in the household.

Dissemination of solar electricity facilitate household to use TV, radio and mobile phone. These three instruments increase household “social awareness” providing news and information as well as “mental recreation” through providing entertainment facilities. Education program increases literacy for children and adults. Education program, Health program, agricultural information and use of modern technology of SHS affect sustainable development in rural area for long run perspective.

4.8.8 Telecommunication

Electricity is necessary for rural telecommunication. In Bangladesh, land line telecommunication is very rare. Emergence of mobile phone captures the telephone market in rural and urban area of Bangladesh. Clear network of mobile phone is now everywhere in the country. In remote rural area SHS provide electricity for charging mobile phone battery. A study conducted by Khalid Md. Bahauddin found that solar system is creating a substantial effect in the telecommunication sector in the off grid areas. Rural people can charge their mobile phones using the SHS. Thus, they can communicate to any one easily. Mobile phones are powered by solar chargers in off-grid areas. It has brought a revolution to communication in the rural villages; more than 200,000 polli phones are in operation in remote areas (Khalid Md. Bahauddin, 2010).

In present survey, it is found that 100% household possesses mobile phones, which indicate broad dissemination of mobile phone in the rural area of Bangladesh. Respondent are requested to answer whether mobile phone is necessary for socio-economic development. All the respondents state that mobile phone is one of the important preconditions for socio-economic development in rural area. When the respondents are requested to state whether SHS create facilities for getting news and

information, 100% respondents have agreed that SHS create facilities for getting news and information. Table-28 expresses the result of getting news and information facilities by SHS in the survey.

Table-28: SHS creates facilities for getting news and information

Does SHS create facilities for getting news and information?	Percent
Agree	23.3
Strongly agree	76.7

Data: Household survey

In survey area, nearly 30% households has foreign employee. Mobile phone enables them to communicate with their near and dear who are working abroad. All of the respondents state that SHS is necessary for charging mobile phone battery in their household. As many family members are working in abroad, video conferencing using laptop through Skype is also becoming popular in the village. In this line of communication SHS is opening a potential window for business and development.

4.8.9 Perceptions of safety and socialization

Safety perception and community socialization are also important factors for socio-economic development in rural area of Bangladesh. SHS illuminate indoor house as well as some area of surrounding households, which increase safety for the household member, specially for the women and decrease stealing in household. Very limited research studied on the SHS electricity impacts on perception of safety and socialization in Bangladesh. In order to find out the community safety perception and socialization respondent are requested to state their opinions regarding safety perception and socialization. Table-29 illustrates the result.

Table-29: SHS increases perception of safety and helps in socialization

Does SHS increase perception of safety?	Percent	Does SHS help in socialization?	Percent
Agree	22.2	disagree	2.2
Strongly agree	77.8	Neutral	48.9
-		Agree	31.1
-		Strongly agree	17.8

Data: Household Survey

In survey, 100% respondents agree that SHS increase safety in their household. Respondents are also asked to state the changes that they observed in household, they frequently state that stealing is decreased for installing SHS. In case of socialization 48.9% household agree that SHS helps in socialization.

Household members feel better security after installing SHS. SHS provides more clear light and facilities for using TV, Radio and mobile phone. These instrument facilities increase easy and frequent movement of household's members and social gathering. Besides, using mobile phone helps in close contact between relatives, friends and neighbors. Furthermore, using SHS in community place like mosque, temple provides more and effective community gathering in rural area.

4.8.10 External impacts of SHS installation

Most of the previous studies stated that SHS use is mainly limited to high and middle-income households due to high initial cost. So, neighboring household member frequently visited the SHS owning household for different purposes. To find out the potential indirect impacts of SHS installation respondents are asked to state the frequency of visit and purpose of the neighbors' household. Table-30 represents the result.

Table-30: Neighboring families visit SHS household and purpose of visits

Does neighboring household visit your household?	Percent	Purpose of visit	percent
Yes	30.0	Charging of mobile phone	12.2
No	70.0	Watching TV and Charging mobile Phone	15.6
Total	100.0	Use of Laptop	2.2

Data: Household survey

About 70% households state that neighboring family does not visit their household for SHS. Only 30% households state positively and the purpose of the visit is to watch TV program, charging mobile phone and use of laptop. At the beginning of SHS

dissemination, only the wealthy household could afford it due to initial high prize. Introduction of micro-financing system increase affordability even the low income households in the rural area. So the percentage of neighboring household visit for watching TV programme is decreasing day by day.

Generally, to use TV need more power than LED light. So the household using low power SHS does not use TV and other high consuming power appliance like laptop, solar fan, blending machine, fridge etc. So the low power SHS- household and SHS-lacking household member visit neighboring household owning TV. Watching TV is the major attraction for households lacking their own access. Charging of mobile phones and use laptop for audio-visual communication through Skype are also performed by neighbor household lack of laptop and SHS electricity. Prevalent TV watching, option of charging mobile phones, audio-visual communications etc in SHS-households enable poorer households to use modern technology facilities. Some poor family live in community use only one tube lights for lighting household from neighboring SHS-household by sharing. Besides, children of nearer poor household use clear light of SHS-household for reading & studying. The visits of non SHS-households to neighboring SHS owned households increase awareness and disseminate knowledge and information in them through TV and Radio programs and access to use mobile phone and laptop.

4.9 Environmental impacts of SHS

Sustainable development is the most concerning issue in the world. United Nations and others global organizations are working to protect the natural environment reducing global warming for human well-being and development. SHS improves the environment by reducing CO_2 and other Green House Gases (GHG). The previous studies also identify the role of SHS for environmental improvement. In present study respondents are requested to give their opinions for role of SHS in environmental improvement. About 74.4% respondents agree that installation of SHS improve environment. Table-31 illustrates the result of environmental improvement by SHS in the survey.

Table-31: Installation of SHS improves environment

Does installation of SHS improve environment?	Percent
Neutral	25.6
Agree	56.6
Strongly agree	17.8
Total	100.0

Data: Household survey

SHS produce electricity using sunlight. As in solar system, there is no involvement of fossil fuel; using SHS for lighting reduce the CO_2 and other GHG emission. Battery life span of SHS is near five years. Lack of scientific management of the SHS battery may contaminate the soil and ground water. Therefore, in rural areas of Bangladesh at the end of life span of the battery, its disposal is a critical issue. In present study, these two most important issues regarding disposal of battery in SHS and its impact in environment are examined.

4.9.1 Disposal of battery in SHS

Solar energy is green, secure and sustainable renewable energy. So electricity produce by using solar energy normally do not pollute the environment. Only battery related waste is the negative impact for environment. Generally, SHS battery life span is about five years. After five years it should be replaced with new one. So every year a lot of batteries have to be replaced. An uncontrolled disposal of battery creates risk of soil contamination and water pollution. In Bangladesh, it is the duty of partner organization of SHS dissemination program to collect old battery from rural household and return it to the manufacturer for recycling purposes. But the collection of all battery from rural area is a challenging work. In this study, to identify the management of battery disposal respondents are requested to state the disposal management of old battery. Table-32 represents the result regarding battery disposal.

Table-32: Disposal of old batteries

Management of Battery disposal	Percent
Do not Know	38.9
Sell in market	54.4
Throw them away	6.7

Data: Household Survey

Nearly 39% households do not know how to dispose of the old battery. More than 54% states that as it is dangerous, they will sell it in the local market and about 7% state that they will throw it away after its life span. Though, the households know that in case of battery failure before the end of the five year warranty period, they will get a new battery free of cost, but maximum household do not know the procedure of battery disposal. From the above data it is very much alarming for the rural area as they do not know the proper way of disposal the battery. Using SHS in Bangladesh is increasing very swiftly. Bangladesh is the fastest growing solar country in the world. Already huge amount of solar battery is disseminated in the rural area. In the study, it is also revealed that 13.3% household are using SHS more than five years, but they do not change the battery with a new one, even they do not know how to change the old battery in the system. Even PO does not visit the SHS household after collecting their installment. Lack of awareness of the customers and lack of seriousness of the PO, the huge number of old battery may create another hazard for the environment, and thereby impede the sustainable development.

4.9.2 Reduction of Green House Gas emission:

Kerosene was the main fuel for lighting in study areas, which is used in “Hurricane” or “Kuppi”. The traditional fuel produced CO_2, which is one of the important sources of GHG. According to IPCC "warming of the climate system is unequivocal", and "most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations." The climate change report outlined the importance of greenhouse gases (GHGs), especially CO_2, for global warming and climate change and emphasised the need for further reducing respective emissions (IPCC 2007a: 10-11, IPCC 2007b: 19). The use of SHS does not produce CO_2 rather saved CO_2 emissions. In order to determine the overall savings of CO_2 emissions from SHS, emissions from kerosene use and emissions resulting from the SHS manufacturing process and transport to the rural areas has to be deducted. But data on CO_2 emissions from the SHS production process

and the distribution of SHS to their place of installation is not available. So, the GHG emissions arise from the transportation and manufacture of SHS is ignored to determine kerosene savings & respective reduction of CO_2 emission.

An early study made by Cabraal shows that kerosene consumption of a household using wick lamps in Sri Lanka was 0.5 to 1 litre per day i.e. 15 to 30 litres per month (Cabraal. A, 1996). IPCC guide line suggests that CO_2 emission from kerosene is 2.5 kg/litre (IPCC, 1996, vol.3). According to a study of Kaufmann emission from kerosene lamp was 2.4 kg CO_2/litre (Kaufmann. S.L,1999). The traditional lamps (Kuppi and hurricane) used by the rural people were tested at BCSIR. The average CO_2 emission from traditional lamps used by the rural people in Bangladesh was 2.41 kg CO_2/litre according to the test (S.M. Najmul Hoque, 2013).

In the study on an average 4.2 litres of kerosene were used in households per month and after installation of SHS 90% kerosene consumption is reduced. Life span of a SHS is 20 years. So average kerosene saved by a SHS is around 3.78 liter/month that means 907.2 liter in 20 years in the household. With a kerosene CO_2 emission factor of 2.41 kg/litre, this equals a monthly replacement of 9.109 kg CO_2 equivalent. One SHS in the study area will reduce 2186.352 kg of CO_2 equivalent emission during its operating life of about 20 years.

4.10 Quantitative measurement of socio-economic development by installing SHS in rural area of Bangladesh.

Both qualitative and quantitative data are collected in the household survey, as quantitative data for all socio-economic variables are not possible. After installation of SHS in household social impacts are found positive by analyzing the qualitative data of some social development variables like health benefit, access to information, employment generation, entrepreneurship, socialization etc. During the survey some variables that can be quantify, quantitative data of those variables are also collected to measure socio-economic development occurred in household after installation of SHS.

The following table-33 illustrates summarize quantitative data of some socio-economic development variables and theirs changes.

Table-33: Quantitative data for some socio-economic development variables and their changes.

Variable		Before installation of SHS	After installation of SHS	Change	Percentage (%)
Household total Income (BDT/month)		7866	9333	+1467	18.64
Study time for education of children (Hour/Day)		5.28	6.74	+1.46	27.65
Quality leisure time for household women and men (Hour/Day)	Women	6.73	8.22	+1.49	22.13
	Men	7.06	7.53	+0.47	6.65

Source: Household survey

It is observable that household total income, study time for children, quality leisure time for household women and men are increased positively. A composite Socio-economic Development Index (SEDI) can be constructed like the Human Development Index (HDI) statistics as follows-

Socio-economic Development Index, (SEDI) = 1/3(Household total income change) + 1/3(Study time change for education of children) + 1/3(Quality leisure time change both for women and men).

Where household total income change reflects cost of living, study time change reflects education and quality leisure time change reflects quality life of the household member. Each of the components receives equal weight.

Whether it is positive or negative using the percentage changes of the three measures of socio-economic development and applying the formula a composite index value will be result, which might be a measurement indicator of socio-economic development in the rural area.

Calculation:

In the present study, using the formula socio-economic development of SHS in rural Bangladesh can be calculated as-

SEDI = 1/3(18.64%) + 1/3(27.65%) + 1/3(22.13% + 6.65%)

= 1/3(18.64%) + 1/3(27.65%) + 1/3(28.78%)

= (6.21 + 9.21 + 9.59) %

= 25.01%

This socio-economic development changes occurred during five years. So mathematically per years socio-economic development change is 25.01% ÷ 5 = 5.002%. This is a positive value which indicates positive impacts of SHS in socio-economic development of rural Bangladesh. From above calculation it can be roughly estimated that over each year socio-economic development is improved positively by 5% approximately in the respective villages. As it is a rough estimation, there must be some valid criticism. To find out actual socio-economic development we need time series data. Further studies are required in this line for better understanding of socio-economic development by SHS in rural area of Bangladesh.

CHAPTER FIVE

CONCLUSION AND RECOMENDATIONS

5.1 Conclusion

Now-a-days the momentum, dynamics and sustainability of a civilization depend on energy. Hence, a country can be considered as civilized one if it has sufficient access to energy as required for the industrial, agricultural and economic growth. There are lots of sectors to use solar electricity in rural area of Bangladesh. Use of solar electricity in household productive work, community health clinics, schools, union-information centres and flood/cyclone centre in the remote and hard to reach areas, would not only enhance quality of life and productivity in the rural areas but also contribute to more rapidly achieve the Sustainable Development Goals (SDGs).

In survey, it is found that micro financing system increases the affordability to purchase a solar system in rural areas. The role of SHS on household income is observed to be quite limited, as SHS electricity is hardly ever used productively. Lack of knowledge & training on productive use of SHS and the non-availability of solar electric appliances are found to be the main reasons for this situation.

The SHS role on social development is more dramatic compared to facilitate on economic development. Clear household lighting and fresh air improve education, health, facilitates in access to information, communication, entertainment, and increase perception on safety. These factors bring radical changes in the traditional social life of rural people. Although the use of SHS electric appliance is rather limited, lifestyle has significantly improved due to the availability of solar electricity. Household members quote households work condition improves due to electric lighting and avoidance of kerosene-related work. Solar electric lighting extends evening hours of household activity. Watching TV, productive activities and the studying of school going children are common activities benefited from the extended evening time. SHS electricity also improves household conditions for education as it provides clear light and fresh air as well as longer studying hours for children. In case of health benefit, it is also found that SHS owned households get improved indoor air, availability of information on health issues as well as reduced accidents related to kerosene use.

SHS-Household get information, education and entertainment for using TV, Radio and mobile phone. Due to widespread ownership of mobile phones, electricity from SHS is becoming an essential factor for telecommunication in remote rural areas, where it constitutes the source of power to charge the cell phone batteries. Increased perception of safety and social activity due to social gatherings for watching TV and listening radio are also observed in SHS owned households.

Reduction of carbon dioxide (CO2) emissions is observed in comparison to former utilisation of kerosene for lighting purposes. But disposal of old batteries constitutes the only potential negative impact of SHS that might represent a serious threat to natural resources. Emphasizing old batteries collection and introduction of reliable battery recycling system can reduce the threat.

Increase economic growth, quality education, health benefit and access to information can significantly improve the productivity, skill and livelihood of the rural people. In combination with other comprehensive rural development programmes, SHS will ensure sustainable socio-economic development in the long run.

Human life directly depends on electricity. In Bangladesh, the generation of electricity is mostly dependent on gas and diesel fuel. Since these resources are limited, solar energy will be the main source of electricity. Researcher, policy maker, development partner acknowledged the immense prospect of solar electricity in rural area of Bangladesh. Despite the potential of solar electricity to catalyse rural development, access to this technology has not been translated into widespread adoption in rural area. Right incentives, policy alignment, development of local technological capabilities, political and institutional support is very much essential for sustainable and effective use of SHS. Now it is high time to integrate structural set up for using this untapped resource.

5.2 Recommendations

It is a myopia view that solar electricity is costly. The higher initial capital cost of installing SHS should not be taken as an index of being expensive, rather the provisions to invest in solar energy sources seem logical. Because most area of the country still cannot access electricity, an energy crisis may have catastrophic effects on livelihoods. Recent studies by the United Nations and World Bank suggest the vulnerability of

developing countries to climate change. So solar energy and other renewable energy sources allow the countries to plan future energy security as well as prepare the country for the future effects of climate change. As Bangladesh is endowed with solar energy, it is possible to secure energy crisis by adopting SHS technology. Using solar electricity will reduce to import high cost of diesel and thereby saves foreign currency. From the findings of the field survey, the following recommendations can be proposed for the role of SHS in order to bring sustainable socio-economic development in Bangladesh.

5.2.1 Promoting productive use of SHS

It is found from the household survey that insignificant income generating activities are promoted by the use of SHS. Solar light is used mainly for household lighting, mobile phone battery charge, running TV and radio. Application of SHS is very limited to providing light for productive activities, like sewing, handicraft making, poultry farming etc. Moreover, due to lack of knowledge and proper training, these applications are not flourished to the remarkable extents. Depending on the demand of household, it is very much essential to disseminate the solar led household appliances for increasing household productivity. Using solar water heating, solar drier, solar lanterns, solar water desalination, solar blending machine, solar sewing machine, solar driven small machines for power looms, solar water pump, solar rice grinding machine can be popularised for increasing household productivity. At the same time proper training and marketing facilities is necessary for increasing household income generating activities. The SHS dissemination organizations should include training for the low income household in their program on how to use the SHS in various productive ways. More studies are also essential for using solar power appliances in socio-economic context of Bangladesh.

Agriculture is still the main income generating activities in rural area. Utilization of solar electricity for agriculture purpose is very limited. Use of solar electricity pump in irrigation, solar electricity in poultry and dairy firm will be beneficial for overall productivity. Therefore SHS dissemination program should be included in irrigation, poultry and dairy farm. The organizations should engage their activities in these areas.

Use of solar electricity in shop and business is profitable. The dissemination of SHS in household business like rural market is very much observable. But use of solar electricity in ICT related activities is very limited. SHS dissemination organizations should include their program to use solar electricity in audio-visual conferencing, repairing shops of TV, Radio, Mobile phone, Laptop, camera, etc. Further detail research is also needed for the productive use of solar electricity in the field of ICT.

5.2.2 Promoting socio-economic benefits of SHS

The prime role of solar electricity is to transform the lives of people in the rural area. Installing SHS households member can work long hours, children can study for a longer period, they can watch television, listen radio, active cell phone handsets by recharging battery, use household appliance for increase productivity and reduce workload. SHS also improves indoor air and reduces kerosene related health hazard.

Lack of electricity, village community health centre cannot use refrigerator and other electricity driven medical equipment. Every community clinic and union health centre could be electrified with SHS and thereby the community people can get health facilities, using SHS refrigeration of vaccines and operation in rural health clinics.

Now-a-days information is power. To decrease digital divide government provides computer with internet facilities in the education institutions. But children of rural poor families, who study in the education institution of remote village, cannot use computer & internet in their institution. Providing SHS in those institutions to run computer and internet, the marginalized poor student could be dragged in the main stream of development.

In survey it is revealed that TV watching and listening of Radio are most frequently conducted throughout the evening hours by household members. To increase benefits from TV and Radio educational TV and radio programmes could be implemented. As most of the household use mobile phone, more messages awareness programme can be provide through it.

People of rural remote village become helpless during disaster period. Electrification by SHS in the cyclone centre or flood centre provides better management of affected

people as it is possible to vaccine preservation, water preservation, cooking, heating and communication public health information through TV, radio and mobile phone.

In remote area of Bangladesh, people do not feel safety at night due to sufficient light. Village street lighting can be possible by using SHS, which increases safety of rural people at night. It can help to improve low and order situation in remote village and thereby ensure good governance.

5.2.3 Promoting awareness building for battery disposal of SHS

SHS is being popular for its green electricity. Only the critical issue of using solar energy is its battery disposal. Bangladesh is the fastest growing solar using country in the world. As in Bangladesh the rural people are not technically sound, uncontrolled disposal of old battery of SHS may create a serious threat for health and environment in those areas. During survey, it is found that household is not aware about the appropriate disposal of old battery. For sustainable rural development and smooth dissemination of SHS it is very much essential to take necessary programme for awareness building regarding battery disposal issues. Already more than five years have passed for SHS dissemination programme in Bangladesh. A large number battery is scattered in rural area. The IDCOL and the PO should take necessary action for awareness campaigns and should strengthen the battery collection and recycling program. Power division of Bangladesh should monitor it regularly emphasizing high priority.

5.2.4 Promoting positive indirect impacts of SHS

In survey it is found that low-income households could not able to improve their living condition of the last years. Through micro finance system SHS has been disseminated dramatically, but still some poor family in village could not afford to purchase it. In this case promotion of sharing existent SHS load with non SHS neighboring household could be introduced. In this way, Non SHS poor households could get benefit of electricity without purchasing SHS. This will help the poor households to get facilities of electricity and reduce the social discrimination. In rural village there are community

values to watch TV and charge mobile phone in SHS-household. So, it is possible to promote additional income generating household business through lending solar light, charging mobile phone, providing refrigeration facilities etc.

5.2.5 Promoting rural Mini grid solar electrification for cluster village:

Rural poor people in Bangladesh live in community enjoying common homestead. Besides, there are many cluster village & community village in remote rural areas where the cost of a grid electricity service will be very high. Those villages can be electrified by using solar mini-grid electrification system.

5.2.6 Promoting innovative application of SHS:

Today SHS is a way of sustainable development in the world. Solar electricity is relentlessly active to involve in many innovative application. More research works need to use SHS in wide range of productive activities efficiently and effectively.

5.2.7 Other recommendations

Bangladesh can meet half of its power demand via the grid. Almost forty percent area of the country still remains in the dark at night where grid electricity cannot reach or is not economically viable. This remote areas and grid lees nonviable areas can be cover with SHS. Government has taken renewable energy policy and it envisioned to supply electricity with 2020. But still a number of problems hinder for the growth of solar electricity.

Prospect of solar energy has been studied by many researcher and international organization. In Bangladesh photovoltaic solar power is being used by many organizations and government agency, but the nodal agency for co-ordinate the operation and Regulatory framework for sustainable renewable energy development is in primary stage.

The controversy around solar technology is that it is expensive. The initial cost of set up solar energy system is very high. People are also unaware about the diverse use of solar power. SHS is basically used in rural area. But rural poor people are incapable of maintenance the technology. Moreover, information regarding solar power is not readily available in the market. Technical training can enable users to do trouble shooting for minor problems such as replacing fuses, adding distilled water, and replacing bulbs. This may avoid technician calls and increase system reliability

The solar energy sector is facing problems with sub standard solar panels and battery. There are complains that the battery quality is not up to mark to achieve satisfying performance. Insufficient warranty period of battery & inverter is another problem. Bangladesh is currently importing almost all of the solar panels; low cost sub standard panels are inundating the market. Instead of using high quality premium priced solar panels, most of the people are using cheap sub standard brands and facing numerous troubles. In that process they are losing their interest in using SHS.

Construction of solar power stations requires extensive infrastructure and equipment. These require a staggering amount of fund most of which will have to be borrowed from foreign donors. Moreover Bangladesh does not possess the necessary technology and raw materials to manufacture the photovoltaic cells (PV), reflectors and other auxiliaries, all of which have to be imported. Maintenance and repairing are also an issue due to the lack of experience technicians in this sector.

In household survey many households frequently stated the limited power supply of the SHS as their main disadvantage. They wanted a higher potential load and battery storage capacity to run more appliances such as ceiling fans, fridge or computer. Therefore, further research is recommended regarding the SHS-households' willingness to pay for the extension and upgrade of the system as well as for respective electric appliances.

In order to remove the impediments and increase effectiveness the SHS in rural area following necessary actions can be taken.

- Sustainable and Renewable Energy Development Authority should be more active to popularize the solar electricity in rural area of Bangladesh.
- Appropriate financial arrangements, including payment installments, fee for services, subsidy, technical and legal support for organizations dealing to set up in the solar sector is necessary.
- Government should foster research programs for harnessing, conversion and consumption solar energy technologies. Demonstration program should be extended more of diverse use of solar energy technology.
- Technician training is essential for developing local technical support, which can also help make the project sustainable. Women also should be invited for training, as they are the main users of the systems and can do some of the maintenance.
- Standard of solar energy apparatus should be ensured through institution.
- To increase acceptability of the technology by user components/accessories of solar systems should be available locally so that the users can buy them easily when required.
- To increase affordability local production of SHS components is necessary to reduce the selling price of SHS.

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ANNEXURE

Annexure -1

Questionnaire on Research Entitled 'The Role of Solar Home System (SHS) in Socio-economic Development of Rural Bangladesh'

The purpose of this survey is to understand The Role of Solar Home System (SHS) in Socio-economic Development of Rural Bangladesh and make suggestions for effective planning and undertaking programs for its development. Please feel free to opine on this questionnaire if you have a useful insight into the subject matter.

Basic data:

Interview date	
District	
Upazila	
Union	
Village	
Code No	

Main interviewee:

☐ Head

☐ Spouse Name----------

Mobile phone no ----------

(A) Demographic information

(i) Basic information of household.

	Name	Sex	Age (year)	Marital status	How many years of schooling completed?
Household Head		☐ Male ☐ Female		Single Married Divorced Widowed	
Spouse		☐ Male ☐ Female		Single Married Divorced widowed	

1) How many people live in your household? ----------
2) How many sons and daughters are in your household? Son--------, Daughter---------
3) How many children attending school/Madrasa/collage are there in your household? Primary school----------, High school ---------- Madrasa ----------. Collage ---------- University ----------.

(B) Socio-economic information

a) Economic

i) Household income

	Present	Before SHS installation
04) What is your occupation?	☐ Farmer ☐ labour ☐ Skill worker ☐ Service ☐ Housewife ☐ Shopkeeper ☐ Business ☐ unemployed ☐ Rickshaw/Van Puller/Driver ☐ others	☐ Farmer ☐ labour ☐ Skill worker ☐ Service ☐ Housewife ☐ Shopkeeper ☐ Business ☐ Unemployed ☐ Rickshaw/Van Puller/Driver ☐ others
05) What is the occupation of your spouse?	☐ Farmer ☐ labour ☐ Skill worker ☐ Service ☐ Housewife ☐ Shopkeeper ☐ Business ☐ unemployed ☐ Rickshaw/Van Puller/Driver ☐ others	☐ Farmer ☐ labour ☐ Skill worker ☐ Service ☐ Housewife ☐ Shopkeeper ☐ Business ☐ Unemployed ☐ Rickshaw/Van Puller/Driver ☐ others
	Present	Before SHS installation
06) How much do you earn in a month (BDT)	☐ 4000-6000 ☐ 6001-8000 ☐ 8001-10000 ☐ 10001-12000 ☐ 12001-14000 ☐ Above 14000	☐ 4000-6000 ☐ 6001-8000 ☐ 8001-10000 ☐ 10001-12000 ☐ 12001-14000 ☐ Above 14000
07) How much does your spouse earn in a month (BDT)?	☐ 4000-6000 ☐ 6001-8000 ☐ 8001-10000 ☐ 10001-12000 ☐ 12001-14000 ☐ Above 14000	☐ 4000-6000 ☐ 6001-8000 ☐ 8001-10000 ☐ 10001-12000 ☐ 12001-14000 ☐ Above 14000

08) Has the general living condition in your household improved, does it stay the same or degrade after SHS installation?

☐ Improved, why? ----------

☐ Stay the same

☐ Degraded, why? ----------

ii) Source of energy for lighting and expenditures

09) What are the sources of household lighting and its expenditures?

Energy source	Energy source use for lighting?	Monthly expenditures(BDT/month)
Candles	☐	
Kerosene	☐	
Electricity by SHS	☐	
Other energy source	☐	

10) What were the sources of household lighting and its expenditures before SHS installation?

Energy source	Energy source used for lighting	Monthly expenditures (BDT/month)
Candles	☐	
Kerosene	☐	
Other energy source	☐	

11) How did you purchase the SHS?

☐ Financing/Installment ☐ Pay whole amount of money

12) If installment, what was the amount of down payment (BDT), monthly installment & total installments?

----------BDT, ---------- BDT per month. ---------- Installments.

13) If you pay whole amount how much money have you paid and how did you manage it?

---------- BDT, From ☐ Household income ☐ Loan ☐ Others

14) How much maintenance cost do you need?

---------- BDT per month.

15) How many years have you been using SHS? ---------- Year.

iii) Productive activities

16) Was/is there any income generating business/production going on in your household?	Present	Before SHS installation
	☐ YES ☐ NO	☐ YES ☐ NO

	Present	Before SHS installation
17) If yes, what kind of income generating business/production was/is there in your household?	☐ Husking rice ☐ Preparing rice (Muri/Phita) ☐ Sewing cloth ☐ Making handicraft ☐ Carpenter workshop ☐ Other----------	☐ Husking rice ☐ Preparing rice (Muri/Phita) ☐ Sewing cloth ☐ Making handicraft ☐ Carpenter workshop ☐ Other----------
18) How was/is average income through business /production per month (taka)?	Present	Before SHS installation
	☐ 3000-4500 ☐ 4500-6000 ☐ 6000-7500 ☐ 7500-9000 ☐ 9000-12000 ☐ Above12000	☐ 3000-4500 ☐ 4500-6000 ☐ 6000-7500 ☐ 7500-9000 ☐ 9000-12000 ☐ Above12000

iv) Entrepreneurship

19) Did installation of SHS create entrepreneurship?

☐ YES ☐ NO

If yes then what is the level? (1=Minimum, 5=Maximum).

1	2	3	4	5

20) Do you sell electricity to others household in your village?

☐ YES ☐ NO

If yes, how much money do you earn by selling electricity per month (Taka/month)?

☐ 50-100 ☐ 100-150 ☐ 150-200 ☐ Above 200

v) Employment

21) Did the use of SHS create any employment opportunity?

☐ YES ☐ NO

If yes which of the following activities?

☐ Agricultural products ☐ Small Business ☐ Making handicraft ☐ Sewing cloth ☐ Others

vi) Working hours

22) How long by average do/did the following persons in your household have to work per day?

	Present (hour/day)		Before SHS installation (hour/day)	
Women	☐ 4-6 ☐ 8-10 ☐ 12-14	☐ 6 -8 ☐ 10-12 ☐ Above 14	☐ 4-6 ☐ 8-10 ☐ 12-14	☐ 6 -8 ☐ 10-12 ☐ Above 14
Men	☐ 4-6 ☐ 8-10 ☐ 12-14	☐ 6 -8 ☐ 10-12 ☐ Above 14	☐ 4-6 ☐ 8-10 ☐ 12-14	☐ 6 -8 ☐ 10-12 ☐ Above 14
Children	☐ 4-6 ☐ 8-10 ☐ 12-14	☐ 6 -8 ☐ 10-12 ☐ Above 14	☐ 4-6 ☐ 8-10 ☐ 12-14	☐ 6 -8 ☐ 10-12 ☐ Above 14

B) Technological: i) Attitude towards technology

23) What are the solar electricity consuming activities in your household?

☐ Watching TV ☐ Listening radio

☐ Reading/ Studying under lights ☐ Household works under lights

☐ Charging of mobile phone ☐ Income generating work under light

☐ Other electricity consuming activities ----------

Please tick mark the following question (1= Strongly Disagree, 2 = Disagree, 3= Neutral , 4 = Agree, 5 = Strongly agree)

24) Is TV beneficial for socio-economic development?	1	2	3	4	5
25) Is Radio beneficial for socio-economic development?	1	2	3	4	5
26) Is mobile phone beneficial for socio-economic development	1	2	3	4	5

iii) Adaptation

27) Are you satisfied with the benefits of your SHS?

☐ Yes ☐ No

If yes then what is the level? (1=Minimum, 5=Maximum).

1	2	3	4	5

28) Men, Women, children who benefits most from electricity supply of the SHS?

☐ Men ☐ Women

☐ Children ☐ Others----------

C) Environmental

29) Did you think installation of SHS improve environment?

☐ Yes ☐ No

If yes then what is the level? (1=Minimum, 5=Maximum).

1	2	3	4	5

30) What do you do with the old battery?

D) Social

31) Could you observed any changes in daily life after installing the SHS in your household?

☐ Yes ☐ No

If yes which of the following changes?

☐ Children reading more ☐ Improve relationship with neighbors

☐ Decrease stealing ☐ Increase people respect

☐ Increase safety ☐ others

32) Do you agree that SHS makes it easy & extend time to read in the evening?

☐ Yes ☐ No

If yes then what is the level? (1=Minimum, 5=Maximum).

1	2	3	4	5

33) Do you agree that SHS improves household environment with decreasing incidence of disease?

☐ Yes ☐ No

If yes then what is the level? (1=Minimum, 5=Maximum).

1	2	3	4	5

34) Do you agree that installation of SHS creates facilities for entertainment in household?

☐ YES ☐ No

If yes then what is the level? (1=Minimum, 5=Maximum).

1	2	3	4	5

35) Do you agree that installation of SHS makes easy for the family to get news and information?

☐ YES ☐ No

If yes then what is the level? (1=Minimum, 5=Maximum).

1	2	3	4	5

36) Do you agree that installation of SHS helps socialization with relatives/neighbors in the evening?

☐ YES ☐ No

If yes then what is the level? (1=Minimum, 5=Maximum).

1	2	3	4	5

37) Do you agree that installation of SHS increases perception of safety in the evening?

☐ Yes ☐ No

If yes then what is the level? (1=Minimum, 5=Maximum).

1	2	3	4	5

38) How do household head, spouse and children spend their time on the activities after sunset?

a) household head	Present	Before SHS installation
Household work		
Productive work/Business		
Socializing with friends/relatives/neighbours		
Watching TV		
Listening radio		
Reading/Studying		
Playing		
Others		
b) Spouse	Present	Before SHS installation
Household work		
Productive work/Business		
Socializing with friends/relatives/neighbours		
Watching TV		
Listening radio		
Reading/Studying		
Playing		
Others		

c) Children	Present	Before SHS installation
Household work		
Productive work/Business		
Socializing with friends/relatives/neighbours		
Watching TV		
Listening radio		
Reading/Studying		
Playing		
Others		

39) Do your neighboring families who are not having a SHS visit your home regularly?

☐ If yes, People from ----------household.

☐ No

40) Which of the following activities the members of neighboring families do in your household?

☐ Watching TV ☐ Listening radio

☐ Reading/ Studying under lights ☐ Household works under lights/appliances

☐ Charging of mobile phone ☐ Income generating work under light

☐ Other electricity consuming activities ----------

41) In the past had there been any accidents in your house relating to use of kerosene or others energy sources?

☐ Yes ☐ No

If yes, which of the following?

☐ Kerosene ☐ Candle ☐ Solar Home System ☐ others

Remarks:

Thank you very much for your kind cooperation

REFERENCES

1. BARKAT, A. (2004): *Bangladesh Rural Electrification Program: A Success Story of Poverty Reduction through Electricity*. Dhaka.
2. Barkat, Abul et. al. (2002). Economic and Social Impact Evaluation Study of the Rural Electrification Program in Bangladesh. Report submitted to NRECA International Ltd.-Partners with the Rural Electrification Board of Bangladesh and USAID for the Rural Power for Poverty Reduction (RPPR) Program.
3. BARNES, D.F. (1988): *Electric Power for Rural Growth*. London.
4. BARNES, D.F. (Ed., 2005): *Meeting the Challenge of Rural Electrification in the Developing World: the Experience from Successful Programs.* Washington, D.C.
5. CABRAAL, A., M. COSGROVE-DAVIES, and L. SCHAEFFER (1996): *Best Practices for Photovoltaic Household Electrification Programs.* World Bank Technical Paper No. 324. Washington, D.C.
   http://www.worldbank.org/astae/reports.htm
6. F. Ahammed and D. A. Taufiq. Case study application of solar PV on rural development in Bangladesh, *Journal of Rural and Community Development*, 2008, vol. 3, pp. 93–103, Online. Available: www.jrcd.ca.
7. FOLEY, G. (1990): *Electricity for Rural People.* London.
8. F.D. J. Nieuwenhout , A. Van Dijk, P. E. Lasschut, G. Van Roekel, V. A. P. Van Dijk, D. Hirsch, H. Arriaza, M. Hankins, B. D. Sharma and H. Wade. Experience with Solar Home Systems in Developing Countries: A Review. *Progress in Photovoltaics Research and Applications*, 2001;9:455-474(DOI: 10.1002/pip.392).
9. German Federal Ministry for Cooperation and Development (BMZ) (2004): *Political Declaration of the International Conference for Renewable Energies (Renewables 2004), 1.-4.6., Bonn.*
   Internet:http://www.renewables2004.de/pdf/Political_declaration_final.pdf (21.04.2007).
10. Global Network on Energy for Sustainable Development (GNESD). *Reaching the Millennium development Goals and Beyond: Access to Modern Forms of Energy as a pre-requisite* [Online].

Available htt:www.gnesd.org/downloadables/MDG_energy.pdf, 2007, ch.1, pp. 1–5.

11. GOLDEMBERG, J. (2000): *Rural Energy in Developing Countries.* In: GOLDEMBERG, J. (Ed.): *World Energy Assessment: Energy and the Challenge of Sustainability.* New York: 367-389.
12. Government of Bangladesh (GOB) (2004): *The Constitution of the People's Republic of Bangladesh.*
    Internet: http://www.pmo.gov.bd/constitution/index.htm (02.03.2007)
13. HANKINS, M. (1993): *Solar Rural Electrification in the Developing World.* Washington, D.C.
14. Hridkamol Biswas & Faisal Hossain, Solar Pump: A Possible Solution of Irrigation and Electric Power Crisis of Bangladesh**,** Military Institute Of Science And Technology, Bangladesh University Of Professionals. Dhaka, Bangladesh, *International Journal of Computer Applications,* (0975 – 8887) Volume 62– No.16, January 2013.
15. H U Chowdhury, Making infrastructure work for the poor: Development benefits of PV systems in two Bangladesh communities. Journal of Energy in Southern Africa, Vol 17 No 2 May 2006.
16. Infrastructure Development Company Limited (IDCOL) (2006): *Projects Overview*. Internet: http://www.idcol.org/files/projects.htm (10.03.2007).
17. Infrastructure Development Company Limited (IDCOL) (2007): *Progress with SHS's installation up to 31 January 2007*.
    Internet: http://www.idcol.org/files/prjshsm2004.htm (10.03.2007).
18. IPCC, Intergovernmental Panel for Climate Change, *IPCC guidelines for national greenhouse gas inventories,* Reference Manual (Volume 3), 1994 and revised 1996.
19. ISLAM, K. (2004): *The "Road Map to Renewable" for Bangladesh. Bangladesh Renewable Energy Newsletter*. Enlarged Issue. Vol. 4 (1&2); Vol. 5 (1&2). 3-30.
20. ISLAM, K. (2005): *Photovoltaic (PV) Market Potential in Bangladesh. Constraints, Future Potential Diversification.* In: EUSUF, M. (Ed.): *Solar Photovoltaic Systems in Bangladesh. Experiences and Opportunities.* Dhaka. 75-84.
21. ISLAM, S.M.F. and AHMED M.F. (2003): *Sustainable Renewable Energy: IDCOL's Experience.* In: *Proceedings of the 3rd International Conference on*

Renewable Energy for Sustainable Development. 2-4 October 2003. Dhaka. 139-145.

22. J. Arne, "Connective power: solar electrification and social change in Kenya," *World Development Report*, 2007, vol. 35. No. 1. pp. 144– 162.
23. Kaufmann S.L(1999): *Calculating, Monitoring and Evaluating greenhouse Gas benefits from Solar Home Systems in Developing Countries*. Internet: http://www.crest.org/repp -pubs/pdf/devGGas.pdf.
24. Khan, S. (2006). An overview of renewable energy sources. *Proceedings of the short course on renewable energy technologies,* 1–6. Dhaka, Bangladesh: Bangladesh University of Engineering and Technology, Centre for Energy Studies.
25. Laxmi, Vijay, Jyoti Parikh, Shyam Karmakar and Pramod Dabrase. *Household energy, women's hardship and health impacts in rural Rajasthan, India: need for sustainable energy solutions.* Energy for Sustainable Development. Vol. V11, No.1, March 2003, page 50-68. Indira Gandhi Institute of Development Research.
26. MIYAN, M. and John RICHARDS (2004): *Energy Policy for Bangladesh.* Dhaka.
27. POPULATION AND HOUSING CENSUS 2011, *SOCIO-ECONOMIC AND DEMOGRAPHIC REPORT*, Bangladesh Bureau of Statistics (BBS), Statistics and Informatics Division (SID), Ministry of Planning. WWW.sid.gov.bd.
28. QUDDUS, M.R. (2003): *Challenges of Disseminating PV in Bangladesh: The Experience of Grameen Shakti.* In: *Proceedings of the 3rd International Conference on Renewable Energy for Sustainable Development. 2-4 October 2003. Dhaka.* 123-127.
29. R. Cabraal, D. Barnes and S. Agarwal. Productive Uses of Energy for Rural Development. *Annual Review of Environment and Resources*,2005, vol. 30, pp. 117–144 [Online]. Available: http: envirn.annualreviews.org.
30. Renewable Energy Policy Network (REN21) (2006): *Renewables Global Status Report 2006 Update*. Washington, D.C.
31. S.M Najmul Hoque et.al, (2013): *International journal of Renewable Energy Research*, 2013, vol.3, No.2.
32. SHAKIR-ul haque Khan, TOWFIQ-ur-Rahman,SHAHADAT Hossain, *A Brief Study of the Prospect of Solar Energy in Generation of Electricity in Bangladesh,*

Multidisciplinary Journals in Science and Technology, Journal of Selected Areas in Renewable and Sustainable Energy (JRSE), June Edition, 2012.

33. SUDING, P. and R. POSORSKI (2004): *Renewable Energy: a Win-Win Option for off-grid electrification?* In: CHAKRAVARTHY G., A. SHUKLA, and A. MISRA: *Renewables and Rural Electrification.* Oldenburg: 71-77.
34. Tarujyoti Buragohain, "Impact of Solar Energy in Rural Development in India". *International Journal of environmental science and development*, vol. 3, No.4, August 2012.
35. United Nations. The Energy Challenge for Achieving the Millennium Development Goals. New York, 2005. [Online]. pp. 15–49. Available: http/www:genesd.org/publication.
36. Wahidul K. Biswas, Paul Bryce and Mark Diesendorf (2001). Model for empowering rural poor through renewable energy technologies in Bangladesh. Environmental Science & Policy 4: 333 – 344.
37. World Bank. *The Welfare Impact of Rural Electrification: A Reassessment of the Cost and Benefits: An IEG impact evaluation*, [Online]. Available: http:www.worldbank.org/ieg, 2008, ch.5, pp. 39–52.

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