Johannes Gutenberg University Mainz
Faculty of Chemistry, Pharmaceutics and Geoscience
Department of Geography

Diplomarbeit / Diploma Thesis

Electricity and Sustainable Development:
Impacts of Solar Home Systems in Rural Bangladesh

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as diploma thesis ('Diplomarbeit') to the Department of Geography of the Johannes Gutenberg University of Mainz in partial fulfilment of the requirements for the degree ('Diplom') in Geography.

Mainz, May 2007

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Acknowledgements

I would like to thank my colleagues at GTZ for providing me with support, assistance, and helpful discussion. Special thanks go to Otto Gomm for offering me the possibility of conducting field work while completing a three-month internship at GTZ office in Dhaka/Bangladesh.

Furthermore, I would like to thank all SHS experts interviewed during my stay in Dhaka providing me with helpful insights into the Bangladeshi PV sector and forthright sharing of their personal opinions and experiences.

A warm ‘thank you’ goes to the whole team of the GTZ office in Dhaka for all the straightforward support. Finally yet importantly, this thesis would not have been possible without Dr. Latif and his team of interviewers providing valuable assistance for the accomplishment of the household survey.

Abstract

This thesis deals with the socio-economic impacts of electrification measures with Solar Home Systems (SHSs) in rural households of Bangladesh and their contribution to sustainable development in rural areas.

After a short outline on concepts for rural electrification and the growing importance of renewable energy sources, the thesis will focus on the impacts of grid-based electricity supply in rural areas of developing countries in general. In this context, the results of seven case studies will be summarised; the methodology will be critically assessed for particular cases.

Following a general description of energy-related problems as well as approaches for electricity supply in rural Bangladesh, the SHSs and respective dissemination programmes will be presented. Afterwards, the methods and findings of an impact assessment study of SHSs in rural Bangladesh will be described in detail. The study is based on data from a household survey in 178 households, interviews with experts, as well as short interviews with shopkeepers and owners of small businesses. From the respective findings, recommendations for ongoing SHS dissemination programmes in Bangladesh will be derived.

The thesis concludes with the following key findings:

- For empirically verifying the direct impacts of rural electrification measures, a mixture of quantitative and qualitative data collection methods is essential. Correlations between electricity utilisation and socio-economic indicators are in particular unsuitable to prove a causal relationship between electricity supply and development.

- The utilisation of SHSs in Bangladesh causes positive impacts, in particular in the areas of education, health, information, communication, conditions for household work, subjective feeling of security and social activity. Some of the positive impacts are not only limited to households owning a SHS, as also some of the neighbouring families benefit in particular from the improved information facilities (TV). As a positive ecological impact, the saving of carbon dioxide emissions through the

substitution of traditional lighting fuels has to be mentioned. The economic impacts of the SHSs are limited to an increase in income of shops and small businesses. Households hardly ever use electricity for income generation.

- SHSs contribute to sustainable development mainly through the improvement of social aspects of rural life (e.g. education, health, information, communication, etc.). However, in the mid and long-term, the general conditions for economic growth might therewith improve. As the existing SHSs hitherto are mostly used by households with high incomes, a future focus on poorer households is essential to avoid intensification of social differences between income groups and enable all social groups to participate in the development process. The introduction of an efficient recycling system for the used batteries of the SHSs is a basic prerequisite for ecologically sustainable development through SHSs.

Zusammenfassung

Die vorliegende Arbeit beschäftigt sich mit den sozioökonomischen Wirkungen von Elektrifizierungsmaßnahmen mit Solarsystemen in ländlichen Haushalten Bangladeschs und deren Beitrag zu nachhaltiger Entwicklung im ländlichen Raum.

Nach einem kurzen Abriss zu Konzepten ländlicher Elektrifizierung und der wachsenden Bedeutung regenerativer Energiequellen beschäftigt sich die Arbeit zunächst generell mit Wirkungen netzgebundener Stromversorgung in ländlichen Gebieten von Entwicklungsländern. Hierbei werden die Ergebnisse von sieben verschiedenen Fallstudien zusammengefasst; das methodische Vorgehen wird im Einzelfall kritisch hinterfragt.

Nach einer allgemeinen Darstellung der Energieproblematik sowie Ansätzen zur Stromversorgung im ländlichen Bangladesch werden die sog. ‚Solar Home Systems' (SHSs) und Programme zu deren Verbreitung vorgestellt. Darauf folgt die detaillierte Darstellung von Methodik und Ergebnissen einer Studie zu Wirkungen der SHS auf ländliche Haushalte in Bangladesch. Die Studie basiert auf dem Datenmaterial einer Haushaltsbefragung in 178 Haushalten, Expertengesprächen sowie kurzen Interviews mit Ladenbesitzern und Kleinstunternehmern. Aus den Ergebnissen der Studie werden Empfehlungen für die laufenden Programme zur Verbreitung von SHS in Bangladesch abgeleitet.

Die Arbeit schließt mit folgenden Kernaussagen:

- Um die direkten Auswirkungen ländlicher Elektrifizierungsmaßnahmen empirisch nachvollziehbar aufzeigen zu können, ist ein methodischer Mix aus quantitativen und qualitativen Datenerhebungsmethoden unabdingbar. Insbesondere Korrelationen zwischen Stromnutzung und sozioökonomischen Indikatoren sind ungeeignet um einen Sinnzusammenhang zwischen Stromversorgung und Entwicklung nachzuweisen.
- Die Verwendung von SHS in Bangladesch führt zu positiven Wirkungen insbesondere in den Bereichen Bildung, Gesundheit, Informations- und Kommunikationsmöglichkeiten, Erleichterung der Hausarbeit, verbessertes

subjektives Sicherheitsempfinden und soziale Aktivität. Einige der positiven Wirkungen beschränken sich nicht nur auf die Haushalte mit SHS, da auch benachbarte Familien insbesondere vom verbesserten Informationsangebot (Fernsehen) profitierten. Als positive ökologische Wirkung ist insbesondere die Einsparung von Kohlenstoffdioxidemissionen durch Verdrängung traditioneller Beleuchtungsmittel anzuführen. Im Gegensatz zu netzgebundener Elektrifizierung beschränken sich ökonomische Wirkungen der Solarsysteme auf die Steigerung der Einkommen einzelner Läden und Kleinstunternehmen. Haushalte nutzen den vorhandenen Strom praktisch nicht zur Generierung von Einkommen.

- SHS leisten insbesondere hinsichtlich der Verbesserung der sozialen Lebensbedingungen (Bildung, Gesundheit, Information, Kommunikation, etc.) einen Beitrag zu nachhaltiger Entwicklung. Mittel- und langfristig können sich hierdurch jedoch auch die Rahmenbedingungen für wirtschaftliches Wachstum verbessern. Da die vorhandenen Systeme bisher meist Haushalten mit höheren Einkommen vorbehalten bleiben, ist eine zukünftige intensivere Konzentration auf ärmere Haushalte unabdingbar, um eine Verstärkung sozialer Unterschiede zwischen Einkommensklassen zu vermeiden und eine Partizipation aller sozialer Gruppen am Entwicklungsprozess zu ermöglichen. Grundvoraussetzung für eine ökologisch nachhaltige Entwicklung durch SHS ist die Einführung eines funktionierenden Recyclingsystems für Altbatterien, welche durch die Nutzung der Systeme anfallen.

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List of Abbreviations

AC	Alternating Current
ACRE	Area Coverage Rural Electrification
AIDS	Acquired Immune Deficiency Syndrome
BDT	Bangladeshi Taka
BMZ	German Federal Ministry for Economic Cooperation and Development (Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung)
BPDB	Bangladesh Power Development Board
BRAC	Bangladesh Rural Advancement Committee
B/W	Black and White
CIA	Central Intelligence Agency
CO_2	Carbon Dioxide
DC	Direct Current
EIU	Economist Intelligence Unit
ESMAP	Energy Sector Management Assistance Program
EUR	Euro
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gas
GOB	Government of Bangladesh
GS	Grameen Shakti
GTZ	German Technical Cooperation (Gesellschaft für Technische Zusammenarbeit)
HDI	Human Development Index
HH	Household
HIV	Human Immunodeficiency Virus
IDCOL	Infrastructure Development Company Limited
IEA	International Energy Agency
IOSD	International Organisation for Sustainable Development
IPCC	Intergovernmental Panel on Climate Change
KfW	Kreditanstalt für Wiederaufbau
kW	Kilowatt

kWh	Kilowatt Hour
LED	Light Emitting Diode
MDG	Millennium Development Goals
MW	Megawatt
NGO	Non-governmental Organisation
NRECA	National Rural Electric Cooperative Association
OECD	Organisation for Economic Co-operation and Development
PBS	Palli Bidyut Samity
PO	Participating Organisation
PPP	Purchasing Power Parity
PR	Public Relations
PV	Photovoltaic
REA	Rural Electrification Administration
REB	Rural Electrification Board
REC	Rural Electric Cooperative
REN21	Renewable Energy Network for the 21st Century
REREDP	Rural Electrification and Renewable Energy Development Project
RET	Renewable Energy Technology
SELF	Solar Electric Light Fund
SHS	Solar Home System
SPSS	Statistical Package for Social Sciences
SSHS	Small Solar Home System
TV	Television
UN	United Nations
UNDP	United Nations Development Programme
UN-OHRLLS	United Nations Office of the High Representatives for the Least Developed, Landlocked Developing Countries and the Small Island Developing States
US	United States
USAID	Unites States Agency for International Development
W	Watt
WBGU	German Advisory Council on Global Change
WHO	World Health Organisation
Wp	Watt-peak

1 Introduction

Solar photovoltaic (PV) and other renewable energy technologies are often referred to as being the energy sources of tomorrow. A study by the German Advisory Council on Global Change (WBGU) in 2003 predicted a growing potential for solar energy as an important energy carrier for the future. A possible scenario was drawn with solar energy covering nearly 30% of global energy demand by 2050, and nearly 70% by 2100 (WBGU 2003: 130). In fact, during the last years improved technologies and decreasing prices have resulted in manifold applications of solar PV, may it be for small-scale purposes such as the decentralised powering of emergency telephones on motor-ways or in large solar power plants. As solar PV systems do not produce any direct greenhouse gas (GHG) emissions, their utilisation as a renewable energy source is furthermore becoming more and more relevant against the background of issues such as rising oil prices and global warming.

In the last decade, the use of Solar PV Systems for electricity supply in rural households of developing countries was increasingly promoted by international development organisations, especially in places where the extension of national gridlines was not an economically viable option. By 2005, 2.4 million Solar Home Systems (SHSs) had been in use worldwide (REN21: 2006).

The case of Bangladesh constitutes a good example for this development. Bangladesh belongs to the group of 50 Least Developed Countries identified by the United Nations (UN-OHRLLS n.d.). Aiming at the promotion of sustainable development (for a definition see Box 1) through the increased use of electricity in rural areas of Bangladesh, more than 100,000 SHS have been disseminated through a SHS dissemination programme funded by World Bank, Global Environment Facility (GEF) and the German 'Kreditanstalt für Wiederaufbau' (KfW) (IDCOL 2007). Additional funding is provided by German Technical Cooperation (GTZ) implementing the Dutch-German partnership 'Energising Development', a programme aiming to provide sustainable access to modern energy services for 5 million people in developing countries (Senternovem 2007).

Box 1: Definition of 'Sustainable Development'

The term 'Sustainable Development' lacks a universally accepted definition. The term was used by the Brundtland Commission which coined what has become the most often-quoted definition of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own need." (UN 1987). Most definitions agree with the following three main constituent parts of 'Sustainable Development' as defined by the International Organisation for Sustainable Development (IOSD):

1. **Economic Growth and Equity** - Today's interlinked, global economic systems demand an integrated approach in order to foster responsible long-term growth while ensuring that no nation or community is left behind.
2. **Social Development** - Throughout the world, people require jobs, food, education, energy, health care, water and sanitation. While addressing these needs, the world community must also ensure that the rich fabric of cultural and social diversity, and the rights of workers, are respected, and that all members of society are empowered to play a role in determining their futures.
3. **Conserving Natural Resources and the Environment** - To conserve the environmental heritage and natural resources for future generations, economically viable solutions must be developed to reduce resource consumption, stop pollution and conserve natural habitats (IOSD 2007).

Source: UN 1987, IOSD 2007

But how can solar electricity contribute to sustainable rural development? The links between electricity access from national grid lines and socio-economic development have been thoroughly studied for many rural electrification programmes in the past. Respective studies identified many benefits for rural electricity users in areas such as income generation, energy expenditure savings, information, education, and health. In contrast, studies solely focusing on impacts of decentral electricity generation with solar PV have been rare. However, as provided electricity loads and respective dissemination approaches considerably differ[1], the link between access to solar electricity and development should be investigated separately. The lack of scientific work on socio-economic impacts of SHSs is particularly evident for the case of Bangladesh, where studies focusing in detail on SHSs and their influence on development have been non-existent.

[1] In contrast to grid electricity, electric loads provided by SHSs are rather small. Therefore, the application of electricity from SHSs is mostly limited to lighting and small electric appliances. Dissemination approaches of SHSs generally involve high costs for the rural customers.

However, the importance of comprehensibly tracing results of development programmes and therewith interventions in the field of solar energy supply, has constantly grown over the last years. Ministries and agencies using taxpayer's money for planning and implementation of development programmes are under special observation to measure and report the results of their ongoing projects and therewith demonstrate the effective use of funds (GTZ 2004: 4). The alignment on international development targets such as the Millennium Development Goals (MDGs) has put additional emphasis on the need to verify development programmes' contributions to these overarching targets. The Paris Declaration, endorsed in 2005, additionally emphasised the need to align all development activities on their respective results for the development process (OECD 2005: 7-8).

1.1 Research objective

In contrast to findings from past grid-based electrification programmes, this study aims at identifying the most important linkages between electricity supply from SHSs and sustainable development as defined by IOSD (cp. Box 1) for the case of rural SHS electrification programmes in Bangladesh. Therefore, four central questions will be in focus of this thesis:

1. What basic methodology is appropriate to identify the impacts of rural electrification programmes?
2. What impacts on the rural population have been identified for the case of electricity supply from national grid lines in developing countries?
3. What impacts can be observed in rural households of Bangladeshi villages with ongoing SHS dissemination?
4. In what way do these impacts promote sustainable development in rural areas?

By answering these questions, this thesis shall contribute to the understanding of development processes facilitated by electricity supply with renewable energy sources. The results of this thesis shall provide crucial information for ongoing SHS dissemination programmes in Bangladesh as well as methodological guidance for future impact assessments of renewable energy programmes.

1.2 State of research

Regarding socio-economic impacts from grid electricity, numerous studies from past electrification programmes are existent. In chapter 3, seven studies have been chosen for further analysis.

For the case of SHSs, VAN CAMPEN et al. (2000) summarise the results of some existent impact studies in their paper 'Solar Photovoltaics for sustainable agriculture and rural development'. The main findings will be included in chapter 5 and related to Bangladesh-specific findings of this thesis.

So far, specific work on SHSs and their development impacts in Bangladesh has been non-existent. However, there have been some attempts to measure impacts of rural electrification by means of grid extension. For example, the broad 'Economic and Social Impact Evaluation Study of the Rural Electrification Program in Bangladesh', funded by the United States Agency for International Development (USAID) and published in 2002 by BARKAT et al., did focus on conventional grid electrification. Overall, results were very positive, identifying numerous benefits of electricity for rural development. This study will be covered in more detail in chapter 3. An unpublished baseline survey of the Rural Electrification Board (REB) in collaboration with the World Bank, conducted in 2005, covered SHS use to some extent. However, the study mainly focused on appliance use and satisfaction in SHS households. Socio-economic impacts were not analysed in particular for the case of solar electricity, but only for electricity in general. Apart from these scientific approaches, most written material on the impacts from SHSs is limited to PR documents of organisations active in the SHS dissemination process. These documents seem to be based predominantly on anecdotal evidence from respective field staff (cp. BARUA 2005: 12-14).

1.3 Study outline

The following four chapters will provide certain aspects of information necessary for understanding the linkages between the use of electricity in rural areas and sustainable development. While chapters 2 and 3 will investigate the general case of rural electrification through grid extension in developing countries, chapters 4 and 5 will analyse the special case of SHS use in Bangladesh. Chapter 6 will conclude by bring-ing together and comparing respective findings and answer the main questions as defined in section 1.1.

To provide some background information on rural electrification in general, **chapter 2** will present basic concepts of rural electrification in developing countries. It will reveal information on the current state of rural electrification in the developing world, the most important modes of electricity supply, as well as the role of renewable energies. This chapter is based on available literature.

In **chapter 3**, general findings concerning the socio-economic impacts of rural electrification will be the centre of analysis. After describing the importance of impact assessments for the case of rural electrification programmes, a number of past impact studies focusing on the extension of the national grid in developing countries will be analysed and compared. The applied methodologies will be critically assessed.

Chapter 4 will reveal detailed information on the context of SHS electrification in Bangladesh providing crucial background information for the following impact analysis. This chapter will describe the rural energy situation in Bangladesh and display the approaches of the existent SHS dissemination programmes. The chapter is based on existent literature and respective project documents.

In **chapter 5**, economic, social, and ecological impacts of SHS electrification will be presented based on findings from a broad field survey conducted by the author of this thesis. Data was gathered from interviews with experts involved in the SHS dissemination process, a survey in 178 households and several short interviews with shopkeepers and owners of small businesses. The applied scientific methods will be described in detail in the first paragraphs of chapter 5.

In **chapter 6**, a general recommendation for impact assessment methodologies will be drawn. Findings on impacts from grid electricity in general and solar electricity use in Bangladesh will be summarised and compared. The impacts identified for SHS electrification in Bangladesh will be analysed concerning their potential for sustainable development as defined by the International Organisation for Sustainable Development (IOSD) (see Box 1). Furthermore, the impacts identified for SHS use in rural

Bangladesh will be assessed regarding their potential to be applied to SHS programmes in other countries.

2 Rural Electrification in Developing Countries

In the 20th century, electricity has become a key driver of the world's transformation. The opening of power stations for urban electricity supply started in 1882 by the Edison Company in London, followed by New York and other bigger cities like Berlin, Milan, and Rio de Janeiro. By the turn of the century, electricity supply systems could be found in most of the major cities in the world. With the development of high voltage transmission technologies in the 1920s, the main urban centres and industrial consumers were connected into grid systems supplied by large power stations (FOLEY 1990: 3-6).

First approaches to rural electrification took off in the 1920s. Supply lines were reaching outer parts of the cities and connected suburban or peri-urban communities and industrial users. Widespread electrification of rural areas then started during the 1930s, mainly in the United States and the more economically advanced European countries (FOLEY 1990: 6). In the United States, the creation of the Rural Electrification Administration (REA) and the introduction of a system of local electricity cooperatives led to a tremendous growth of rural electrification, a burst of new rural productivity and dramatic improvements in the quality of rural life (BARNES 1988: 17).

In many countries of the developing world, electricity companies were set up around the same time as in industrial countries. The first power stations in Jamaica and Sri Lanka were established in 1892 and 1895 respectively. Many of the respective electricity companies were subsidiaries of those in the industrial world. Rural electrification progress, however, was much slower compared to the industrial world (FOLEY 1990: 8-9). Early electrification projects in countries such as Colombia, Ecuador, and the Philippines were expected to promote development like that which had occurred in the United States in the 1940s and 1950s. These expectations, however, were not realised. In the early 1970s, the US Agency for International Development (USAID) was the first donor agency with major involvement in rural electrification of developing countries. The US model of rural electrification by means of electricity cooperatives had become an exportable item and under USAID programmes the model was later replicated in the Philippines (1969), Thailand (1972), Costa Rica (1975), and Bangladesh (1978) (BARNES 1988: 17-19).

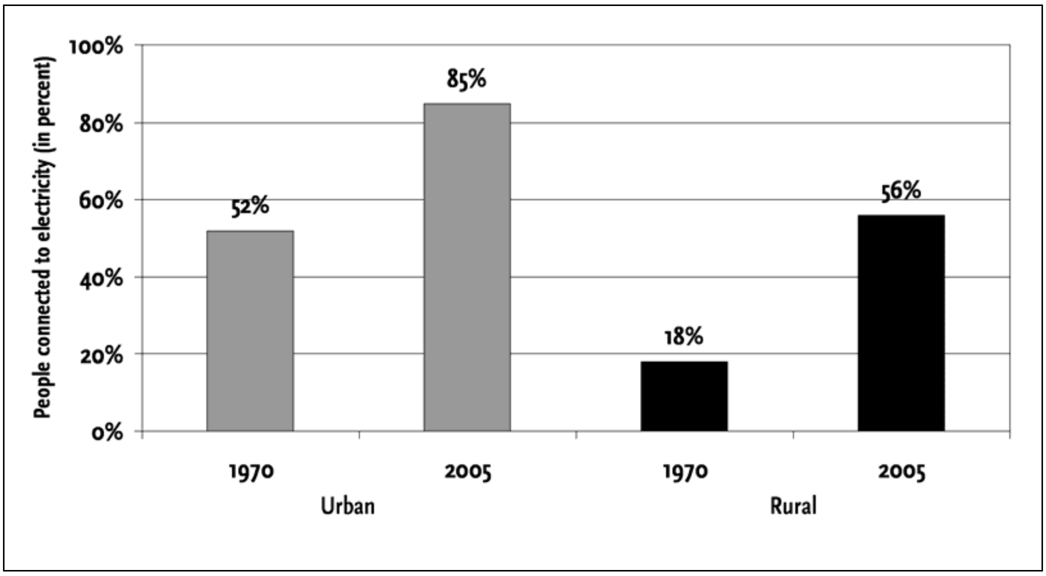
Today, complete electricity coverage has been achieved even in the remotest areas of industrialised countries. In 2005, rural electrification rates in transition economies and OECD countries were on average 98.1% (IEA 2006: 567). In contrast, the International Energy Agency (IEA) stated in its World Energy Outlook 2006 that only about one quarter of the total world population has access to electricity. 80% of those without electricity live in rural areas of developing countries (IEA 2006: 157). Today, bearing in mind the economic growth and social progress accredited to electrification of rural areas in industrialised countries, most rural electrification efforts are concentrated on developing countries. In most cases, rural electrification programmes are supported by international donor organisations.

The following paragraphs will focus on the current state of rural electrification in developing countries. After describing the general problems of rural electrification in the developing world (section 2.1), common practices of rural electricity supply will be presented in section 2.2. Section 2.3 will discuss the growing importance of renewable energies in the context of rural electrification programmes.

2.1 Current state and problems

In 2005, the rural electrification rate in developing countries was cited 56% compared to an urban electrification rate of 85% (IEA 2006: 567). These figures had changed dramatically from 52% (urban) and 18% (rural) in 1979 (Barnes 1996: 42) (see Figure 1). Between 1970 and 1990 alone, nearly 1.3 billion people were newly supplied with electricity from national grids, of which 800 million gained access in urban and 500 million in rural areas. China accounted for nearly half of this development (BARNES 1996: 41). The extent of rural electrification varies greatly between different world regions (see Table 1). In certain countries especially in Sub-Saharan Africa, the proportion of rural people with access to electricity is frequently as low as 10%.

Figure 1: Urban and rural people connected to electricity in developing countries, 1970 and 2005 (percent)



Data: Barnes 1996, IEA 2006; Illustration: Michael Blunck

Table 1: Electricity access in developing countries by world regions, 2005

	Electrification rate (%)	Urban electrification rate (%)	Rural electrification rate (%)
North Africa	95.5	98.7	91.8
Sub-Saharan Africa	25.9	58.3	8.0
China and East Asia	88.5	94.9	84.0
South Asia	51.8	69.7	44.7
Latin America	90.0	98.0	65.6
Middle East	78.1	86.7	61.8

Data: IEA 2006

But what are the major obstacles for rural electrification in developing countries? FOLEY (1990: 11) described rural electricity supply in developing countries as a “formidable task”. In developing countries, rural electrification is taking place under less favourable circumstances than those faced by the industrial countries when carrying out their own programmes. Average rural incomes are low, large numbers of people live near subsistence level. Therefore, the ability to pay for electricity is small. In most cases, rural populations live dispersed, settlements are scattered over large areas resulting in poor capacity utilisation efficiency for transmission and distribution systems and other energy infrastructure (FOLEY 1990: 12). The low population densities mean that electricity distribution costs must be spread over relatively few people resulting in high costs for each unit of electricity consumed (BARNES 2005: 8). In certain cases, providing an electricity line to a few rural households can result in an energy cost of up to seven times the cost of providing electricity in an urban area (GOLDEMBERG 2000: 369). Thus, rural populations are often given low priority by governments when it comes to electrification programmes even though constantly rising populations and the continuous expansion of new farming areas mean that the task of rural electrification is continually growing (FOLEY 1990: 12, GOLDEMBERG 2000: 369). However, as BARNES (2005: 9) points out, the cost of rural electrification can "be minimized if design standards are modified appropriately, and the choice of technology is based on both financial and potential socioeconomic benefits to a community or region".

2.2 Modes of rural electricity supply

Providing access to electricity can be achieved by two basic technical concepts: by means of centralised supply as well as 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). National grids generally link all the main demand centres and power stations into a single, centrally controlled inter-connected system. A distinction is usually made between the transmission system and the distribution system. The transmission system consists of a limited number of high voltage lines. It is used to send large amounts of power at high voltages from power stations to the areas of highest demand. The voltage is then stepped down and the power is fed into a sub-transmission system or directly in the distribution system which takes it to the consumers (FOLEY 1990: 23).

The tendency in many rural electrification programmes has been to extend the grid incrementally, connecting towns and villages in order of increased capital cost. Therefore, remote, less-densely populated areas were likely to be the last gaining access to electricity. High transmission and distribution costs are keeping private or public utilities from quickly connecting remote areas to the national grid (GOLDEMBERG 2000: 375). GOLDEMBERG (2000: 375) specifies the main reasons for these high costs as follows:

- The capacity of power lines is inefficiently used because of the low population density.
- Demand levels are very low.
- Villages may have very undiversified daily or seasonal demand profiles.
- Line losses tend to be very high.

On the other hand, the extension of national grids offers many advantages for rural electrification programmes. As the supply of electricity comes from a network of linked power stations it is generally more reliable than acquiring electricity from a single source. Compared to decentralised approaches, the need for repair and maintenance is limited, as wires, poles and transformers need little attention. As rural demands are generally small in relation to the capacity of the grid as a whole, no technical problems are caused by the rural load demand varying on a daily or seasonal basis. Furthermore, grid extension provides a certain degree of flexibility regarding future increase of demand. Unfortunately, in many developing countries these advantages of grid supply are almost nullified by the fact that the national electric grid is subject to frequent breakdowns and interruptions of supply. Therefore, rural electrification based on grid extension can suffer severe problems. In many cases, especially where the possibility of improvement in the national system is low, it may make sense to rely on decentralised approaches instead, even in areas close to the national grid (FOLEY 1990: 39-40). However, in industrialised as well as developing countries “grid extension is by far the most common method of providing power for rural electrification” (FOLEY 1990: 39).

In contrast, **decentralised approaches** for rural electricity supply are becoming more and more attractive for electrification programmes in developing countries (GOLDEMBERG 2000: 375). As SANGHVI (2001) pointed out as a lesson learned from past World Bank electrification programmes, “Grid extension is sometimes not the most cost-effective solution; decentralized delivery options and alternative energy sources--such as solar Photovoltaic, mini-hydro and other renewable energy sources--should be considered, following the principle of least-cost development” (SANGHVI 2001). With a decentralised electricity supply, access to power is not provided by a national grid, but instead generated locally near the place of consumption. One main advantage of decentralised electricity supply is the avoidance of high costs for transmission and distribution networks (GOLDEMBERG 2000: 375). Two main strategies can be distinguished for decentralised power supply. Small isolated distribution system, so called **mini-grids**, supply a group of households with energy from a shared source. The most common energy sources for mini-grids are diesel generators, small-scale hydro-power, small photovoltaic power stations, or diesel-wind hybrid systems (FOLEY 1990: 43-65). Apart from decentralised mini grids, households or commercial electricity users can satisfy their electricity demand by the use of **stand–alone systems**. These 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-level. Most common technologies in use are diesel generators, solar photovoltaics and small wind generators.

2.3 The growing role of renewable energy technologies

Renewable energy sources such as solar insolation, wind, or hydropower are in principle available on an indefinitely sustainable basis, whereas fossil resources (e.g. oil, coal, gas) are available in finite quantities. In the 2004 Update of the World Energy Assessment GOLDEMBERG et al. (2004: 48) stated that “[...] renewable energy sources [...] may be highly responsive to environmental, social and economic goals.” He mentions seven main advantages of their utilisation for future energy supply:

- Diversification of energy carriers, technologies and infrastructure,
- improving access to clean energy sources,
- reducing the use of fossil fuels and thus saving them for other applications and future use,
- increasing the flexibility of the power system as electricity demand changes,
- reducing pollution and emissions from fossil energy systems,
- reducing dependency and spending on imported fuels, and
- job creation.

Additionally, renewable energy technologies (RETs) are well suited to small off-grid applications in remote rural areas as the respective energy sources like sunlight, wind, or biomass are widely available in most places of developing countries (GOLDEMBERG et al. 2004: 48). The local autonomy of RETs is a significant advantage compared to grid connections and diesel generators, which are considerably dependent on external supplies (SUDING et. al 2004: 76). A study by the World Bank in 2005 revealed that -

assuming availability of the respective renewable energy source - RETs are the least-cost option for off-grid stand-alone electrification in rural areas. Furthermore, numerous RETs constitute potential least-cost options for electricity generation in mini-grids (World Bank 2005: 9).

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 the following years, the significance of using renewable energy carriers for covering worldwide energy demand was repeatedly brought up in international meetings and conferences, with growing emphasise put on the role of electricity in the context of socio-economic development in developing countries (CECELSKI 2002: 10). Attending the International Conference for Renewable Energies held in Bonn in 2004, ministers and government representatives from 154 countries acknowledged "[...] that renewable energies combined with enhanced energy efficiency, can significantly contribute to sustainable development, to providing access to energy, especially for the poor, to mitigating greenhouse gas emissions, reducing harmful air pollutants, thereby creating new economic opportunities, and enhancing energy security through cooperation and collaboration" (BMZ 2004: 1).

Below, the most important RETs commonly in use for decentralised rural electricity supply are briefly introduced.

2.3.1 Small-scale hydropower

For thousands of years, hydropower has been used for milling and other mechanical applications. Today the majority of modern small-scale hydropower plants are solely used for electricity generation. The first electricity generation with hydro plants dates back to the beginning of the 20th century. In 1914 there were about 7,000 installations in Switzerland, the vast majority with an output under 30 kW. Small hydro plants have also been widely used in the developing world, often in combination with commercial farms or missionary posts (FOLEY 1990: 46-47). Small-scale hydropower plants are often divided into three categories: micro hydro (less then 100 kW), mini hydro (100-1,000 kW), and small hydro (1-30 MW). Plants of 50 kW and above can be used to electrify communities or small regions by establishing mini grids. Turbines below 1 kW are sometimes used as stand-alone systems for the supply of individual households. They are installed at the end of hosepipes and provide unreliable but serviceable results. These so-called pico hydro systems have been in use mainly in China and Vietnam (GOLDEMBERG 2000: 375).

Design, construction, and operation of small hydro plants are complex tasks and have to be carefully planned, especially when the local community will be in charge of the plant management (FOLEY 1990: 47). Experience with small-scale hydropower is evidence that the plants can become drivers of the local economy, as building and operating the system creates new jobs, while their maintenance requires technically trained personnel (SUDING et. al 2004: 76). In many cases, a major drawback of small hydro plants is their lack of reservoir capacity. The water is obtained from running water bodies and not stored in big reservoirs, therefore seasonal variations in power output may occur. Thus, the long-term viability of small-scale hydropower regularly has to depend on backup electricity, which is supplied either locally or through the national grid (GOLDEMBERG 2000: 375-376). On the other hand, when there are adequate preconditions for mini hydro plants (e.g. water availability, good storage capacity, low construction costs) small-scale hydropower is more cost-effective than diesel systems (SUDING et. al 2004: 72).

Costs are highly variable depending on the size of the plant, site topography, proximity of the site to the main load area, and hydrological conditions. They vary between about 6.8 US cents/kWh for a 5 MW mini hydro plant and 14.6 US cents/kWh for small (300 W) pico hydro installations (World Bank 2005: A13-A19).

2.3.2 Solar photovoltaics

The direct conversion of sunlight into electricity is called photovoltaic solar energy conversion. An essential part of a 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. Photovoltaic modules are usually mounted at an angle in order to increase the amount of sunlight falling upon them (FOLEY 1990: 57). In 1999, 10 percent of photovoltaics sold worldwide were used for off-grid applications in rural areas of developing countries (GOLDEMBERG 2000: 376). Photovoltaics can be used in a variety of system designs for rural electrification purposes.

One approach is the PV mini-grid. These systems use a large array of modules at a central location, and then distribute the power to customers through distribution lines. Experience shows that this approach "is both technically viable and problematic [...]" (Hankins 1993: 9). As up-front capital demand is high, it is usually supported by donor aid efforts and not easily sustained by rural communities themselves. On the other hand, the systems are difficult to expand once installed (Hankins 1993: 9). One of the biggest limitations of PV mini grids is their restricted output, which has in many cases led to great dissatisfaction among users. Combined with poor reliability in practice (which can cause major problems, as repair and maintenance of PV power stations are quite sophisticated tasks) these systems have not yet been proven as a viable application for rural electrification (FOLEY 1990: 60-61). Therefore, there are only few examples of locally planned and installed PV mini-grids in the developing world (Hankins 1993: 9). However, under certain conditions, in combination with diesel or wind generators so-called hybrid systems can become a serious alternative for the powering of rural mini-grids. These systems have lately gained renewed attention, after being under demonstration since the 1980s (VAN CAMPEN 2000: 8).

More common in rural electrification programmes is the use of solar PV as standalone systems in households, social institutions, or places of productive or business activities. Generally, these systems are referred to as 'Solar Home Systems' (SHSs). The provided loads are low (typically less than 100 W), but can be sufficient for the powering of lights, radios, television sets, and to refrigerate medicines at rural clinics. The most important obstacle to wider deployment of these small systems is the limited financing available in rural areas, especially with the necessary battery storage being a major cost factor. The poorest households often cannot afford these PV systems (GOLDEMBERG 2000: 376). More detailed information on technical, operational, and financial aspects regarding this technology will be presented in chapter 4.

Compared to existent subsidised tariffs of rural grid electrification schemes, PV technologies cannot compete (SUDING et. al 2004: 74). World Bank states costs of electricity from solar PV varying between about 50.8 US cents/kWh for mini-grid application (25 kW) and 65 cents/kWh for 50 W Solar Home Systems (World Bank 2005: A1-A6). Lower costs can be achieved with PV-wind hybrid systems: World Bank states costs between 19.9 cents/kWh (stand-alone 300 W) and 30.9 cents/kWh (mini-grid 100 kW) depending on the system size (World Bank 2005: A15-A18). Even though PV technology 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 and infrequency or the procurement costs of fuel are very high, so that even diesel generators cannot compete (GOLDEMBERG 2000: 376, SUDING et. al 2004: 72). Without major cost reductions, photovoltaic technology will be limited mainly to remote household and other small-scale applications, as the provision of higher loads for manufacturing or even most cottage industrial applications would be too expensive (GOLDEMBERG 2000: 376). However, with continuously rising fuel prices photovoltaic technologies may become more cost-efficient than off-grid alternatives based on fossil fuels.

2.3.3 Wind

Wind energy is broadly available but diffuse. A region's mean wind speed as well as its frequency distribution are important factors for the amount of electricity that can be produced by wind turbines (ROGNER 2000: 163). Wind energy was widely used as a source of power before the industrial revolution, but later replaced by fossil fuels because of differences in cost and reliability. The oil crisis of the 1970s triggered renewed interest in wind energy for grid-connected electricity production, water pumping and power supply in remote areas (TURKENBURG 2000: 230). For rural electrification programmes, there are two main approaches to include wind technologies: village-scale wind-diesel hybrid systems and household-level stand-alone units.

For communities far from electric grids that are being served by diesel generators a wind-diesel hybrid system may be an alternative option. When wind conditions are sufficient, the wind generator feeds into the mini-grid while in times of less wind available the generator adds up to fulfil the full load demand. Being installed in many parts of the world these systems can lead to lower electricity costs and less air pollution compared to the use of conventional diesel generators. The used wind turbines typically have capacities of 5 to 100 kW. However, many components of these hybrid systems are based on technology developed in industrialised countries, and the costs of these imported systems are often high (GOLDEMBERG 2000: 377).

Another approach to provide access to electricity at scales where neither grid power nor mini-grid power from diesel units is cost effective is the use of household-scale wind turbines with about 100 W. These units can be used in wind-rich regions and offer benefits similar to those offered by SHSs. For example, this technology has been developed, produced, and deployed in China, mainly in the Inner Mongolian Autonomous Region, where around 130,000 small-scale wind energy systems have been installed, providing electricity for lighting, radios, television, and small appliances mostly to rural herdsmen. Through local production of the system components, the system is cost-efficient (GOLDEMBERG 2000: 377).

Still in many cases, wind technologies tend to be expensive and not particularly reliable. For off-grid electrification, the costs of electricity produced from wind turbines varies between 17.1 cents/kWh for 100 kW systems and about 29.7 cents/kWh for 300 W stand-alone systems (World Bank 2005: A7-A14). Maintenance is a problem since wind turbines seem to be particular prone to minor technical faults. As is the case for SHSs, the need to provide sufficient battery storage to cover windless periods can be a major cost factor (FOLEY 1990: 65).

2.3.4 Biomass

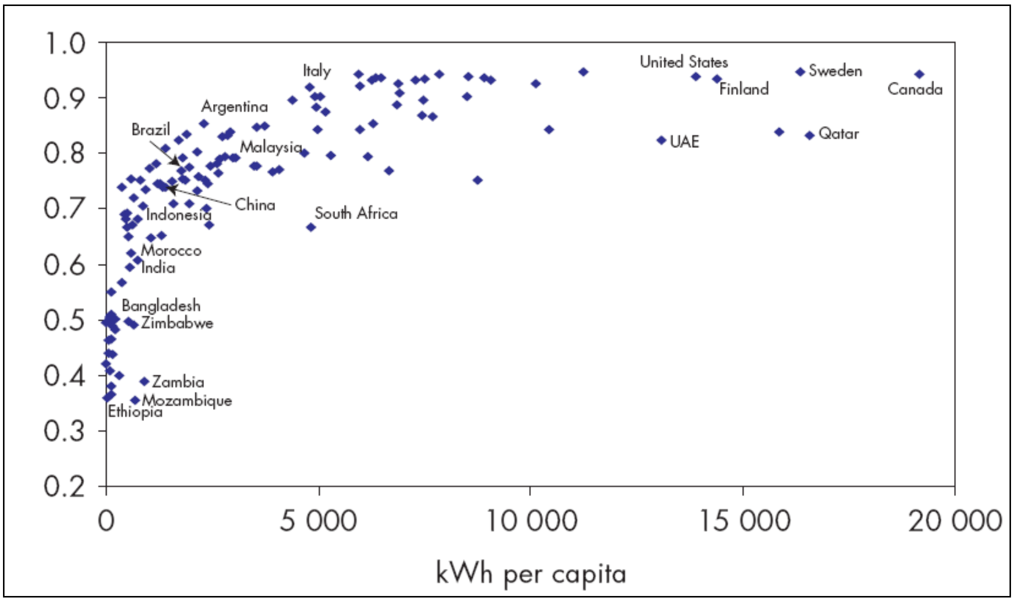
The small-scale gasification of biomass and its use in gas turbines or gas engines for electricity generation is a growing commercial technology in some developing countries, most notably China and India. In India, for instance, there are already 70 MW small-scale biomass gasification systems for off-grid power generation (REN21 2006: 11). In many cases, rural agricultural industries use this technology for their own small-scale electricity supply (REN21 2005: 30). Costs of electricity from biomass gasification are quite low with about 8.7 cents/kWh for a 100 kW system (World Bank 2005: A29-A33). However, biogas on household level is still mainly used directly for cooking or lighting purposes without any intermediate step of electric power generation.

3 Impacts of Rural Electrification

Rural electrification programmes in most cases aim higher than just providing an electricity connection. They aim at improving the overall living conditions of rural populations in economic as well as social terms.

The linkages between energy systems and economic growth are apparent and well understood (Goldemberg 2005: 47). Many empirical analyses have demonstrated that the availability of energy is a driving factor for a country's economic development (IEA 2004: 331). However, the relationship between energy systems such as the availability of electricity and human development has attracted much less attention until recently.

Figure 2: HDI and electricity consumption per capita, 2002



Source: IEA 2004

Figure 2 plots per capita electricity consumption against the UNDP Human Development Index[2] (HDI) ratings for the largest OECD and non-OECD countries. The correlation is strong and non-linear. The increase in HDI scores is most rapid relative to electricity use at low levels of consumption (IEA 2004: 338). Nevertheless, is this correlation reason enough to argue that access to electricity promotes human devel-

[2] The Human Development Index is a summary measure of human development comprising three basic dimensions of human development: health (life expectancy at birth), education (adult literacy rate & gross enrolment ratio) and economic standard of living (GDP per capita in purchasing power parity terms) (UNDP 2006a)

opment? Statistical correlation can give indications for causal relationships, but it does not substitute the need for investigating the actual linkages.

This chapter will focus on these linkages, as it will analyse the impacts of electricity access in rural areas of developing countries. Section 3.1 will emphasise the growing importance of impact assessments in the context of development cooperation and, as an example, present the GTZ 'management for results' approach. Section 3.2 will then present and compare actual impacts identified for past grid-based rural electrification programmes.

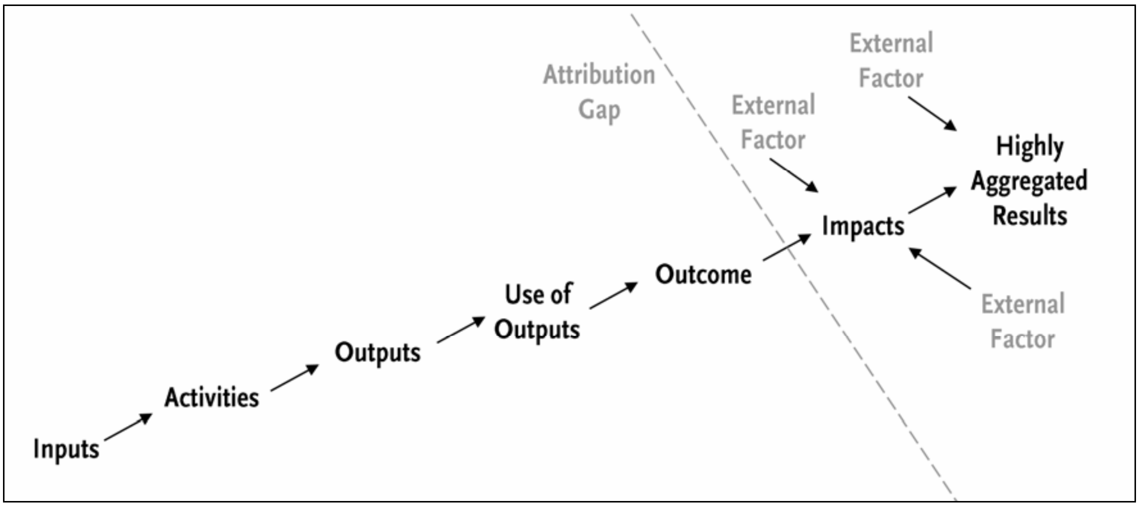
3.1 Results orientation and the GTZ 'Management for Results' approach

During the last few years, identifying the results and effects of development projects and programmes has gained growing concern. International Development Agencies have to prove their projects' contribution to international development targets such as the MDGs. Furthermore, they have to plausibly demonstrate the effective use of funds, thus making a relevant contribution to the economic and social development in developing countries (GTZ 2004: 4). This growing concern for assessing impacts of development interventions was further emphasised in the Paris Declaration of 2005. It pointed out the need for aligning all development activities on their respective results for the development process in developing countries (OECD 2005: 7-8).

Increased orientation on projects' results has already been implemented in management procedures of many International Development Agencies. GTZ and its 'Management for Results' approach is a good example of this development. GTZ's approach aims at aligning all project monitoring activities on project results. This stands in sharp contrast to 'quality at entry' or input-based management approaches which have been in use in the 1990s (GTZ 2004: 4).

The GTZ results model is displayed in Figure 3. Development projects and programmes are resourced through German and partner inputs, such as materials, equipment, staff, and funds. Using these inputs, the projects launch activities such as advisory services, trainings, funding, or accompanying measures (e.g. awareness and marketing campaigns). Through these activities, outputs are generated, such as qualified institutions/organisations, availability of sufficient financial resources of partner organisations or supporting measures in place. These outputs are then utilised by target groups or intermediaries (use of outputs), e.g. leading to efficient processes and improved services of institutions/organisations or the use of funds for improving the energy infrastructure. This use of output is further generating medium-term and long-term development results such as outcomes (e.g. improved access to electricity for rural households) and impacts (e.g. increased household income, reduced workload for women). These impacts can directly contribute to highly aggregated results, such as targets formulated on MDG-level (e.g. improved education, reduced poverty, etc.). In the past, GTZ claimed accountability only for its project outputs. With GTZ's 'Management for Results' approach, project accountability[3] was shifted to the outcome level with overall orientation on expected impacts. As often not all changes related to impacts and highly aggregated results can be solely accounted to the project outcome (e.g. household income is not only influenced by the availability of electricity, but also by other factors), a so-called 'attribution gap' was included in the model to illustrate this issue (GTZ 2004: 8-10).

Figure 3: The GTZ results model



Source: GTZ 2004; Illustration: Michael Blunck

Figure 4 displays an exemplary results chain for the case of electric lighting for educational purposes. As in this case, the detailed project concept of providing electricity to rural households is not of specific concern, the results chain is limited to project

[3] formulated as the overall project target

outcome, impact, and highly aggregated results. It becomes obvious that it is the level of project impacts that constitutes the missing link between access to electricity (the project 'outcome') and overall development (the 'highly aggregated results'). In this case, it is the use of electricity for reading and studying and therewith connected longer studying hours that constitutes the causal relationship between electricity access and improved education.

It is therefore important to assess rural electrification projects regarding their impacts, i.e. direct results from electricity access, to make assumptions on contributions on overall development processes.

Figure 4: Potential impact level of results chain 'electric lighting and education'

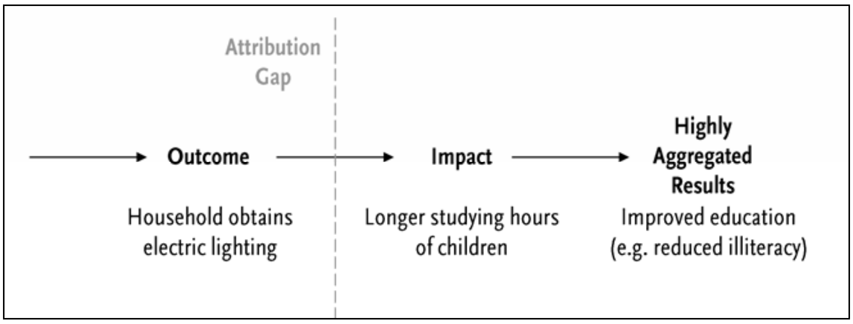


Illustration: Michael Blunck

3.2 Impacts of grid-based rural electrification programmes

Arguments in favour of rural electrification have often centred on its potentially powerful transformative effect on economic as well as social conditions of rural households. CARRASCO et al. (1987: 20) give an optimistic example showing some possibilities that electricity offered for families in Peru at night (see Box 2).

Box 2: Example of changes in daily life due to electricity use in Peru

Balthazar C. returns from his work in the fields at 6 p.m. Last year, after having assured himself that the livestock were all gathered and in the stable, followed by a brief chat with his family and a bite to eat, he and his family would retire to rest no later than 7 or 8 p.m. "in order to save candles". Now, while his wife produces yarn from her ball of wool under the lightbulb which illuminates the room used as a kitchen and a livingroom, he turns on the television to watch the news. The eldest son, leaning on the table, is doing his homework. They retire to bed after 9 or 10 p.m.

Source: Carrasco et al. 1987: 20

In fact, there is a wide range of potential direct changes mentioned in the literature that may occur in households of rural areas after gaining access to national electric grids. There are many studies focusing on impacts regarding economic as well as social aspects for rural populations in developing countries. Many development programmes worldwide have been assessed and evaluated regarding the benefits and constraints that have emerged with the arrival of electricity. The following sections will give an overview on the main results of selected former studies regarding impacts of electricity in rural areas. Table 2 gives an overview on the case studies utilised for this analysis. When describing the impacts of electrification, both electrification of the respective households as well as electrification of the household's surrounding, e.g. of businesses, schools or other households, are taken into account. As most rural electrification programmes in the past have focused on the extension of the national grid, experience in these studies was gained within the context of grid extension.

Table 2: Case studies on impacts of grid-based rural electrification utilised for analysis

Author	Title	Year	Regional Focus
Carrasco, V. et al.	Electrification and Rural Development	1987	Peru
Barnes, D. F.	Electric Power for Rural Growth	1988	India, Indonesia, Colombia
Wamukonya, L. et al.	Socio-economic Impacts of Rural Electrification in Namibia	1999	Namibia
Bronwyn, J. et al.	The Impact of Electrification on Rural Health Care Facilities, Education and Small Businesses	1999	Namibia
Barkat, A. et al.	Economic and Social Impact Evaluation Study of the Rural Electrification Program in Bangladesh	2002	Bangladesh
Energy Sector Management Assistance Program (ESMAP)	Rural Electrification and Development in the Philippines: Measuring the Social and Economic Benefits	2002	Philippines
Halim, S.	Gender and Rural Electrification: A Case from Bangladesh	2005	Bangladesh

3.2.1 Income through production, business, and agriculture

The improved financial condition of rural households and consequential economic welfare is often described as a key element of rural development and a precondition for poverty alleviation. The fostering of economic circles as a basis for rising household incomes is one of the benefits most often related to the arrival of electricity in rural areas. On the one hand, rural electricity supply is held responsible for the development and increased productivity of decentralised rural industries and businesses offering employment and income for rural populations. On the other hand, household manufacturing such as weaving or sewing is a common phenomenon in rural areas of developing countries. These cottage industries are stimulated and can benefit from increased productivity. Furthermore, higher agricultural production by the use of machinery and electric appliances (e.g. water pumps) can contribute to a rise of income.

BARNES (1988: 89) summarised in his classic study 'Electric Power for Rural Growth' that "rural electrification does have a significant impact on rural industry and commerce". Comparing studies from India, Indonesia and Colombia he points out that electricity may be a key factor for the establishment and survival of rural businesses. Comparing areas with and without electricity BARNES found that the number of businesses was generally higher in areas with electricity compared to non-electrified areas. Furthermore, electricity supply seemed to lead to a higher demand for business and industrial labour. Yet, BARNES added to his findings that even though electricity seemed to improve the condition of rural industries, the overall level of industry even in regions with electricity still remained relatively low. "The expectation that electrification will lead to an explosion of business activities in rural areas is likely to remain unfulfilled" (BARNES 1988: 90). He pointed out that in many cases lack of electricity was not the main reason for the failure of small businesses. Instead, this was consequence of internal business problems like poor management or low education level of the business leader, combined with external constraints like insufficient road infrastructure, market conditions, and access to capital (BARNES 1988: 66-91).

With respect to household production, BARNES (1988: 79) revealed that most of the cottage industries with electricity in India, Indonesia, and the Philippines had extended working hours and improved income for their households. However, the use of appliances or power tools was found to be very limited. The main benefit arose from improved lighting facilities (BARNES 1988: 79, 90).

Regarding agricultural activities, the study revealed very little impact on agricultural development for Colombia and Indonesia. This was mainly reasoned with the non-existence of promotion programmes for the agricultural use of electricity. In Indonesia for instance, many farmers were unaware that electricity could be used for irrigation pumping. In contrast, for India the study indicated that rural electrification stimulated agricultural pumping, enabling increased numbers of farmers to crop their fields more than once a year. To some extent, agricultural innovations like the use of hybrid seeds seemed to be facilitated by the existence of electricity. Both factors, pumping and agricultural innovations were associated with a growth in agricultural yields (BARNES 1988: 62-63).

CARRASCO et al. (1987: 36) came to similar insights regarding the increase of industries after the introduction of electricity supply in rural Peru. Besides industries that already existed before electrification and used the newly provided energy to be more productive (mills, sawmills, workshops, beverage factory), there were also incidences of new productive activities due to electricity supply.

In Bangladesh BARKAT (2004: 10) analysing the data of a broad impact study on the national rural electrification programme found that more than 40% of all households with electricity reported that electric power in their household had somehow influenced an increase in income. Additionally, most households stated that the availability of electricity outside of their household (e.g. in industries) had positive influence on their household income. Electrified industries generated on average eleven times more employment than the non-electrified ones. The employment situation especially for women had increased significantly (BARKAT et al. 2002: 179-198). Turnover in electrified retail shops was two times higher than in non-electrified shops. This was mainly due to longer opening hours in the evening, attraction of more customers and better availability of goods and service in electrified markets (BARKAT et al. 2002: 209, HALIM 2005: 4).

Furthermore, BARKAT (2002: 51-53) stated for Bangladesh that the working hours and therewith production in existing cottage industries had increased due to better lighting conditions. Additionally, new cottage industries had emerged in the rural areas.

BARKAT (2004: 6) gave an estimate of 1.1 million people directly involved in farmlands using electrified irrigation equipment. Before gaining access to electricity, diesel pumps were very common for irrigation purposes. After the introduction of electric water pumps, increased crop intensity and production could be observed and previously fallow land became available for cultivation. Due to these factors income from agricultural production increased. Simultaneously expenditures for irrigation declined after the switch from diesel to electricity (BARKAT et al. 2002: 177-178).

In Namibia BRONWYN et al. (1999: 49) concluded that electrification was a marginal issue for small business development in rural areas. Instead, factors like access to markets, finance, or information were more important in most cases. The economic impact of electrification on rural small businesses in Namibia were found to be minimal as none of the small businesses gaining access to electricity reported any increase in income due to the improved energy supply. WAMUKONYA et al. (1999: 15-16) stated for rural households in Namibia that “electrification does not seem to have had any significant impact on growth of income-generating activities”. Surprisingly, household production was found to be lowest in households with electricity access. Less than 1% of home businesses used electricity for productive purposes, and this mainly for lighting. The study concluded that “there are other factors that have to be in place to support business development and that electricity is, at best, a facilitating factor”.

The Energy Sector Management Assistance Program (ESMAP) study on the Philippines did not analyse the impact of electricity on local industry and business development. However, the study revealed that households with electricity were more likely to have some form of home business. As a main finding regarding home business development, the study stated that “Areas with electricity have more home businesses; they are operated for longer hours and are more profitable” (ESMAP 2002: 56-59). The study interestingly showed no evidence of increased agricultural output or income as a result of electricity-powered irrigation (ESMAP 2002: 60).

In conclusion, it can be stated that access to electricity can increase household incomes by improving the employment situation and productivity of rural industries, commerce, household production and agriculture. However, it has to be pointed out that electricity is in many cases not the only factor affecting these developments. Education, adequate road infrastructure, supporting market conditions, and access to capital are examples of other preconditions that have to be met to improve rural economic cycles. Furthermore, the economic benefits seem to be highly dependent on the implementation strategies of rural electrification programmes, e.g. the existence of promotion activities for productive or agricultural use of electricity or the embedding of electrification measures in wider programmes for economic development.

3.2.2 Energy expenditures

The monetary situation of rural households could possibly improve through potential savings occurring through the shift from traditional fuels to electricity and related changes in energy expenditures.

CARRASCO et al. (1987: 19-20) came to the finding that there were significant savings for households using electricity instead of candles and kerosene for lighting. In the case of Peru, households on average had paid five times more for candles and kerosene than they did for electricity after getting access the national grid. Electricity use for cooking was nonexistent and therefore no changes in the expenses for cooking fuels could be determined.

The impact study of BARKAT et al. (2002: 64-66) verified for Bangladesh that expenditures for kerosene (mainly used for lighting purposes) were on average reduced by more that 50% through the use of electricity. However, setting this reduction of expenditures for kerosene in relation with average expenditures for electricity in electrified households these savings diminished to zero (BARKAT et al. 2002: 136). Instead in most electrified households the monthly electricity bill exceeded the monetary savings from the replacement of kerosene.

WAMUKONYA et al. (1999: 6) found in the Namibia case that by gaining access to electricity, energy expenses for rural households increased by up to three times. Particularly for low-income households these additional expenditures on electricity were stated to be a considerable burden on the household budget.

Recapitulating, reduced household energy expenditures due to the shift from other energy sources to electricity are mainly limited to lighting. Substitution of kerosene or other fuels by electricity may lead to fewer expenses for lighting purposes. Although when analysing the results of former studies this seems to be highly dependent on local context, e.g. factors like national subsidies on kerosene and electricity (BARNES 1988: 97) and the technologies in use. Therefore, no general statement can be made regarding monetary benefits from energy expenses through the use of electricity.

3.2.3 Time use and length of day

Many social impacts described in the following paragraphs can be mainly accredited to the availability of electric lighting in the evening. Due to improved lighting people can go to bed later at night gaining additional time for different activities after sunset. This especially applies for developing countries, as most of them are located within the tropics where early sunsets occur throughout the whole year. Advocates of rural electrification often mention activities such as studying, working, productive activities, social visits, and entertainment benefiting from an increased day length (BARNES 1988: 103).

BARNES (1988: 97) cited that it was found in many previous studies that electric lighting extends the day of rural households by two to three hours. Interestingly, he himself stated for the Colombia case, that people in electrified households went to bed only about 20 minutes later than they did before electrification. However, men and women had greatly altered their living patterns to accommodate television viewing in the evening, substantially reducing the time for other activities of adults such as reading, productive activities, social visits, and radio listening. On the other hand, the studying time of children significantly increased. In a direct comparison, BARNES described the situation in India as rather different. There were no changes in sleeping patterns observable in India. BARNES mainly accredited this to the non-existence of televisions in households during the time of research (BARNES 1988: 103-105).

For Peru CARRASCO et al. (1987: 20-21) stated that after gaining access to electricity people tended to stay up at least two hours longer than before. The extended time was used for activities that could only have been accomplished earlier with great effort under the light of a kerosene lamp or candle, such as separating seeds or reading and studying.

BARKAT et al. (2002: 114) mentioned an extended time between sunset and sleep of up to one hour for members of electrified households in Bangladesh. The most dominant activities during this time were stated as watching TV and listening to the radio (all household members), business (men), household chore and sewing (women) and studying (children). A decrease in social activities such as visiting neighbours and gossiping was thereby notable.

The study of WAMUKONYA et al. (1999: 14-15) revealed for Namibian households that the day of household members extended by about 1.5 hours due to electrification. The main activities during this time were stated as watching TV (all household members), reading (children), and socialising (adults).

It seems to be without controversy that access to electrification, and therewith-improved lighting conditions, lead to extended hours of activity between sunset and bedtime. Nevertheless, the benefits from this additional time are highly dependent on the respective activities performed during this time period. Television seems to be an important pastime taking in a significant portion of this extra time in most rural areas of developing countries. Furthermore, in most cases the evening hours are also used for increased productive activities by adults and the studying of children.

3.2.4 Household workload

Many studies on rural electrification emphasised impacts relating to reduced efforts for household-related work due to the availability of electric lighting and household appliances.

BARNES (1988: 96) especially mentioned household appliances as an important factor for improving the situation of women in rural households. By the use of electric irons, refrigerators, blenders and washing machines, labour and time for household work could be saved. BARNES, however, added that the use of appliances was highly related to the income levels of rural households. Therefore, women in poorer households would not benefit in the same way as women from wealthier households.

CARRASCO et al. (1987: 16) mentioned the use of domestic appliances as a benefit of rural electrification programmes in Peru. However, they had not specially investigated this issue.

An interesting finding of HALIM (2005: 3-8) was that the workload of Bangladeshi women in electrified households remained the same as in non-electrified households.

However, women in electrified households had better possibilities to organise their work more conveniently, e.g. by finishing certain work in the evening that was previously only done during daylight.

The study of ESMAP (2002: 55-56) mentioned that many households stated that due to electricity they now could finish their household work in the evening hours.

Recapitulating, access to electricity can provide improved conditions for household work through increased household lighting and the use of domestic appliances such as irons, refrigerators, or sewing machines. This especially affects female household members as they are mostly in charge of household-related activities.

3.2.5 Education

One aspect emphasised in almost every publication on electrification impacts is the potential benefit for education. Besides improved lighting conditions and children having more time available for reading and studying in the evening hours, village schools can offer improved educational services and therewith provide better framework conditions for rural education.

BARNES (1988: 122) found out that in India and Colombia, "rural electrification is significantly associated with education. Even at the same levels of income, households with electricity were likely to have a higher level of education than their counterparts without electricity". He states that conditions for children's reading had improved in the study areas with electricity due to improved lighting at night. Besides the qualitative improvement of studying conditions, children spent substantially more time on reading than before the household had gained electricity access (BARNES 1988: 103).

CARRASCO et al. (1987: 21) also noted benefits for education due to convenience for students of studying under electric lights. However, besides these qualitative improvements, this study did not investigate any quantitative increases in studying hours. It was mentioned that public education services were likely to improve with time, as there were plans to introduce evening classes in schools and libraries with electric lighting (CARRASCO et al. 1987: 24).

For Bangladesh BARKAT et al. (2002: 80-81) identified higher literacy rates in households with electricity compared to households without electricity. They additionally found that the rich-poor divide in literacy was much less pronounced in the electrified than in the non-electrified households: "[…] electricity has a neutral impact on literacy of the rich, but it has significant impact on the literacy of the poor especially that of the poor women" (BARKAT et al.: 2002: 81). Children of electrified households reported better marks in their last examination. Additionally, most of the interviewed electrified households associated improvements in examination results with the availability of electricity. The average amount of time spent on studying by school children after sunset was 23 minutes longer for households with electricity compared to households in non-electrified villages. BARKAT et al. (2002: 84) stated the availability of fans and better lighting and therewith-associated improved comfort of studying as the main reason for these figures. Confirming this assumption 93% of the interviewed electrified households stated that because of electricity in their households the attention and willingness to study had increased.

For Namibia WAMUKONYA et al. (1999: 14-15) stated that electricity in households was often used for the lighting of activities such as reading or studying. Around 20% of the daily hours additionally gained by electric lighting were used for these activities. Complementing the work of WAMUKONYA et al. (1999), BRONWYN et al. (1999: v-vi) focused on impacts of electrification on rural schools. They observed that schools in general made very limited use of their electric lighting as most classes were held during the day. Only in some cases, there were adult education classes or community and church meetings held in the school building after sunset. Schools with attached hostels made much more use of electric lighting as students were able to study at night in the lighted classrooms. However, all interviewed teachers argued that there was not a direct correlation between access to lighting and the achievement of students. Besides lighting, electricity enabled schools to use teaching aids and administrative equipment. Teachers highly appreciated the use of overhead projectors, televisions, tape recorders and video machines, as they made teaching more easy, interesting, and exciting for students. Regarding office equipment, photocopiers were considered most useful as they helped saving a considerable amount of money for copying at other schools or institutions. It was stated that "in the long-term it is possible that primary and combined schools will have more teaching aids and office equipment which will enhance their ability to teach" (BRONWYN et al. 1999: vi).

The survey of ESMAP (2002: 39-47) revealed that most households believed that electricity had positive effects on their children's education, mainly due to improved lighting enabling students to study in the evening hours. Students in electrified households spent on average 48 minutes longer studying per day. As a potential negative impact of electricity, the availability of TV was mentioned as being a danger to detract from school children's study time.

The biggest part of literature regarding benefits of electrification put considerable emphasis on the positive impacts for education. In fact, improved lighting seems to be a major factor for easier und extended studying for school children. Whether this will result in better performance at school or an improved overall educational situation in rural areas in the long term is still not absolutely assured, although some studies (e.g. BARKAT et al. 2002) suggest it. However, there might be other factors, e.g. children's workload or household expenditures for education, which may have more influence on educational performance. Although not covered in detail in many studies, the improved situation of educational infrastructure such as village schools through the use of lighting and teaching aids may positively influence education in rural areas. The example from Namibia (BRONWYN et al. 1999) shows that there is potential for better quality of education by giving electricity access to rural education facilities.

3.2.6 Health

The positive effects of electricity access on aspects of rural health are frequently noted in the literature. Benefits may arise from increased awareness regarding health issues through specific TV programmes, improved indoor air quality, or improved conditions and performance of rural health facilities like health centres or small clinics.

CARRASCO et al. (1987: 23-24) reported no direct impacts on rural households' health situation. However, they pointed out indirect benefits such as the better equipment of a local health centre.

BARKAT et al. (2002: 85-96) found out that in Bangladeshi households with electricity people were much more aware of health issues such as HIV/AIDS, danger signs of pregnancy or avoidance of problems with arsenic water. Most people having knowledge about these issues in electrified households reported that TV was their main source of knowledge. The study revealed that there was a high correlation between household electricity access and health indicators such as professional treatment of diseases, the rate of assisted childbirths, infant mortality rate, immunization coverage, use of sanitation facilities and others. Unfortunately, the study lacked any meaningful explanation for why electricity access should have any influence on the mentioned figures. Therefore, the direct linkage between availability of electricity and the health situation could not conclusively be demonstrated.

In Namibia WAMUKONYA et al. (1999: 14) stated that 49% of grid-electrified households thought that the health of household members had improved since gaining access to electricity. Again, these figures were not further explained or reasoned. Even the households themselves "found the link with health tenuous" (WAMUKONYA et al 1999: 23), but in general reported positive impacts. BRONWYN et al. (1999: ii-v) focused on benefits for the rural health infrastructure. Health facilities used electricity mainly for lighting, refrigeration, radio communication, and powering of medical equipment. The principal benefit of lighting was its use for emergency treatments at night, and admission of over-night patients for observation. Refrigeration was very important for many rural clinics, as vaccinations need constant cooling. The study further revealed that many rural health facilities were keen on using electrical suction machines. Additionally, it was pointed out that another potential benefit of electricity supply might be that qualified medical staff was more attracted to hospitals with electrified accommodation facilities.

For the Philippines, ESMAP (2002: 48-51) observed that households generally had the impression that the use of kerosene for lighting could cause health problems because of indoor air pollution. Thus, electricity use for lighting could have positive impacts on people's health. Furthermore, many households stated that electricity was a very important factor for water supply from a municipal water system, which is generally much safer regarding contamination with disease-causing bacteria than the use of water from lakes, rivers, or wells. However, using simple measures like days missed from work/school and self-reported illness a direct relationship between electricity use and the health situation of households could not be drawn.

Interestingly, access to electricity is often claimed to have positive impacts on household health although statistics on health aspects often reveal no direct relationship. It is unquestionable that the reduction of kerosene fumes and the resulting cleaner indoor air due to the use of electricity in households should have positive impacts on the occurrence of certain illnesses, such as respiratory diseases. However, as there are many other more important factors existent influencing disease occurrence, such as water quality, sanitation or cooking practices, it might be difficult to prove any direct statistical relationship. Nonetheless, electricity can provide a beneficial background for positive development in the health sector due to the potential use of TV for the spreading of health-related information and improved provision of health services through electrification of rural medical infrastructure.

3.2.7 Information and entertainment

One aspect frequently discussed by advocates and adversaries of rural electrification programmes is the multifaceted impact of television and radio use. For instance, some may consider television-viewing good as it helps integrating households into the larger society, while other may criticise it for taking time away from productive activities or more direct social interactions (BARNES 1988: 96).

BARNES (1988: 105-106) stated that "The social impact of television obviously is a two-edged sword." In certain cases, he found out that social and productive activities in the evening were replaced by television viewing. Nonetheless, using a TV enabled many villagers to broaden their horizon, gain information about new technologies for work, and learn about new products through advertising.

CARRASCO et al. (1987: 34) described television as an "agent of change" regarding cultural effects of rural electrification in Peru. It was seen as an entertainment medium, but interestingly above all as a medium for national and international information, "for finding out what is happening in the world" (Carrasco et al. 1987: 34). It was stated that radio and television could lead to the formulation of new concepts about the local reality, life and the world. The possession of a TV carried great prestige among rural populations. It was often among the first appliances people wished to purchase (Carrasco et al. 1987: 34-35).

BARKAT et al. (2002: 85) see TV as an important agent for the spreading of health-related information. Additionally, they noted increased knowledge of women on gender-related topics such as prohibition of dowry, laws about divorce, women's rights, etc. (Barkat et al. 2002: 109-110). When directly addressing rural households about their perception regarding social changes due to TV use, responses were diverse: TV provided a rapid flow of news and information and changed people's mind-set, broadened the scope and opportunities for children's education and enhanced recreational opportunities, improved health, hygiene and nutrition related knowledge (Barkat et al. 2002: 123).

For Namibia, WAMUKONYA et al. (1999: 14-15) reported a significant proportion of evening hours used for TV watching. The study was limited to a brief analysis of the use of educational programmes on TV. It was found that only 6% of the electrified households watched educational programmes on TV. Potential reasons for these figures (e.g. availability of educational programmes on national TV networks) were not given. The impact of TV or radio on rural populations was not further investigated.

Households in the Philippines perceived radio and TV as a good source of entertainment as well as of news and information. Electrified households reported fewer difficulties in obtaining news and information than did non-electrified households. Although even non-electrified households were using battery-driven television sets, the average usage time was much higher in electrified households. As previously mentioned as a potential negative impact, many respondents believed that television could distract school children from studying (ESMAP 2002: 51-54).

It seems that the use of radio and TV may have impacts on several different aspects of social life: education through the use of educational programmes as well as availability of national and international news, health by providing health-related information and awareness, or gender-related issues by spreading of respective gender-related information. Certainly, these impacts are highly dependant on the availability of respective programmes. Nevertheless, radio and TV can be an agent of social change if appropriately used for dissemination of information. Apart from these more obvious impacts, many electrified households simply enjoy the possibilities of improved entertainment facilities. Still, negative impacts like the loss of time for productive or social activities such as children's studying also have to be considered.

3.2.8 Perceptions of safety

A social impact of electrification, which is not often emphasised but is still mentioned in almost every work on benefits of rural electricity supply, is the increased feeling of safety in electrified houses. Improved lighting in households or businesses can contribute a lot to prevent theft or robbery in rural households which have formerly been "in the dark". Furthermore, security of mobility can be positively affected.

BARNES (1988: 97) detected "a greater feeling of safety and security" for families in electrified households. Furthermore, households in electrified communities felt less isolated with the advent of electric lighting in their villages.

In Peru CARRASCO et al. (1987: 34) stated that through nocturnal lighting, safety increased for rural populations. Improved illumination made it safer to move at night and therefore encouraged an increase in socialising activities such as visiting neighbours.

BARKAT et al. (2002: 123) reported for the surveyed households in Bangladesh that 98% of households, irrespective of access to household electricity, stated that protective security had increased due to electrification at household level. As light was available throughout the night and at front side and backyard of houses incidences of robbery and theft were reduced. Furthermore, security of mobility increased due to better visibility at night and less fear of harmful animals such as snakes or insects.

WAMUKONYA et al. (1999: 14) in Namibia came to the finding that most of the electrified households felt much safer at night due to immediate access to electric lights. BRONWYN et al. (1999: 18) investigated on security in rural health facilities. They concluded that theft and robbery which were very common in rural Namibian clinics might possibly be reduced due to improved lighting of clinic premises. However, they pointed out that in most electrified facilities burglaries continued despite the presence of lighting and security guards. Nevertheless, the important psychological effect of lighting was emphasised as patients and staff felt much more secure at night due to electric lights around the clinic premises.

ESMAP (2002: 54-55) stated for the case of the Philippines that electricity supply increased rural households' sense of security in their homes after dark. Although most households even without electricity confirmed that they feel safe in their homes, those with electricity generally had a stronger feeling of security than those without access.

Recapitulating, from the above studies it can be derived that electricity supply has positive impacts on the sense of security in rural households. As the study of BRONWYN et al. (1999: 18) showed, in exceptional cases, this feeling may not be justified as vulnerability for theft and robbery may not decrease significantly. However, it is self-evident that in general improved lighting in households probably may discourage criminal elements from burglary. Furthermore, increased safety of mobility and therewith-connected increased social activity are potential benefits from improved lighting in electrified villages.

3.2.9 Migration

The fast growth of metropolitan areas with all the negative effects of overpopulation is a common phenomenon in developing countries. Migration from densely populated rural areas into urban centres is one of the main reasons for this development. When discussing the reasons of rural migrants to move into the city, it is often referred to the so-called push and pull factors (KNOX et al. 2001: 150-151). Pull factors are certain conditions in target regions of migration that act like a magnet pulling migrants to move into certain areas. For urban areas in developing countries, these might constitute the availability of jobs, higher incomes, or a higher standard of living. The corollary is the push theory, which is focusing on the reasons of migrants to leave their current place of residence. In the rural-urban context, these factors might be low employment possibilities, overpopulation, poor education, and inadequate infrastructure in the rural areas. Therefore, advocates of rural electrification programmes often expect that the anticipated improvement in the quality of life and therewith diminishing of push factors will keep rural populations from migrating, and thereby reduce problems associated with overurbanisation. However, critics claim there is no evidence for this interrelation at all (BARNES 1988: 110). It is sometimes even brought into the discussion that electrification might cause increased out-migration due to improved socio-economic development and rising expectations (BARNES 1988: 111). In the following, the findings from the analysed studies regarding electricity and its impact on rural-urban migration are summarised.

BARNES (1988: 111-118) studied the impact of electrification on rural-urban migration separately for the case of India and Colombia. In India, villages with electricity featured higher permanent out-migration - that is typically movement to towns and cities for employment and education - compared to villages without electricity. BARNES related this trend to increased productive and economic developments in electrified villages, leading to rising expectations of rural populations to improve their living and education standards in urban areas. For Colombia, BARNES could not prove any relationship between rural electrification and migration, and related this to the limited productive impact of local electrification programmes.

Regarding migration patterns CARRASCO et al. (1987: 28) stated for Peru that "electrification alone does not seem to be a sufficient condition to diminish emigration." They reasoned this by assuming that electricity itself already required a favourable socio-economic and cultural context. Therefore, electricity alone could never alone be referred to as an innovation which in itself could detain the emigrational movements. Their study showed no statistical evidence of population movements which could be attributed to electricity access. In contrast, the study mentioned a potential future increase of rural emigration due to concentration processes in agricultural land properties assisted by rural electricity supply (CARRASCO et al. 1987: 28-29).

In the context of rural Bangladesh, BARKAT et al. (2002: 129-130) identified marriage, labour, and education as the most important reasons for migration. The study revealed that out-migration was more evident in electrified households. The higher economic status of most electrified households might give them better possibilities to migrate permanently for jobs or educational reasons. At the same time, BARKAT was able to identify a phenomenon of in-migration from non-electrified villages to rural areas with electricity in seasonal and permanent form. The study revealed that this demographic concentration in electrified rural communities was due to increased employment opportunities (establishment of new economic activities, higher agricultural productivity and thus increased demand for labour during harvesting), as well as better educational and health facilities.

In Namibia WAMUKONYA et al. (1999: 16) did not detect any noticeable impact of electrification on migration flows. Irrespective from electrification status, the number of persons moving to or from the rural area was almost balanced. The most important reasons for in-migration as well as out-migration of rural communities were cited as work and education.

Interestingly, not a single one of the analysed studies could prove any direct relationship between the availability of rural electricity supply and a decrease in rural-urban migration. In fact, the studies of BARNES (India) and BARKAT (Bangladesh) even revealed quite the contrary. In certain cases, rural electrification might thus be a causing factor for increased population movements from rural into urban areas. Higher economic status and education in electrified households seem to be factors facilitating or encouraging rural populations to move to the cities and benefit from better working and educational conditions (e.g. universities).

3.2.10 Beneficiaries of electricity access

Rural communities are not homogeneous in consideration of household conditions such as income, health, and education. In fact, in many cases there is a high degree of inequality notable. There may be wealthy landowner households as well as small huts of poor agricultural labourers side by side in the same community. Furthermore, on household-level there are different household members present, such as men, women, or children. When electrifying a certain village, do all members of the community benefit the same way?

BARNES (1988: 151-153) stated that surveys in Colombia and India showed that households with higher income generally benefited the most when a village obtained access to the national electric grid. These wealthier households were the ones that had sufficient financial resources to afford the installation and monthly charges of an electricity connection, as well as appliances for household work and entertainment. BARNES (1988: 153) cited that "[...] rural electrification programs may be inequitable for a long period of time." Nevertheless, he pointed out that the long-term benefits of rural electrification seemed to be less inequitable, since more families even of lower income groups adopted a connection after a considerable amount of time. Furthermore, increased demand for agricultural labour due to electricity supply was mentioned as a potential way to improve the income situation even of poorer households. Regarding the impacts on different household members, it was generally stated that women and children benefited most from household electrification, as they spent most of their daily time in the household (BARNES: 1988: 151-153). Especially women could benefit from reduced working hours due to the use of electric household appliances (BARNES: 1988: 96). The study concluded that "Rural electrification is one of the few development programs not specifically designed to help women and children which nevertheless have very favorable consequences for them." (BARNES: 1988: 152).

The study of CARRASCO et al. (1987: 28) did not focus in particular on inequalities within electrified communities, however, it was specifically mentioned that the number of electrical appliances used was highly dependent on household income. Therefore, the use of blenders, televisions, and refrigerators as well as associated positive impacts was limited to households with middle or high incomes.

BARKAT et al. (2002: 48) revealed that in Bangladesh electrified households had an average income more than twice as high as households without electricity in the same villages. BARKAT et al. therefore drew the conclusion that electricity led to higher household income. On the other hand, however, the study of BARKAT et al. did not mention whether people with high income were maybe more likely to gain an electricity connection. In her paper "Gender and Rural Electrification: A case from Bangladesh" HALIM (2005: 3-8) summarised and analysed the gender-related findings of BARKAT's 1992 study of electrification impacts in Bangladesh and came to the conclusion that women represented one of the main beneficiary groups of Bangladesh's rural electrification programme. She stated improved employment and income opportunities as one major benefit for women in electrified villages and households. The employment situation of women had increased significantly as "Industrial activities have increased and [...] led to increased employment and [...] to the growth of the skilled female labour force that considerably exceeds that of the male". This development was mainly due to increased labour demand of industries in the textile sector (e.g. spinning mills). Furthermore, free time in the evening was often used for TV watching and listening to radio programmes, contributing to the development of the women's knowledge base. Women in electrified households had much higher knowledge on fundamental rights and gender issues than women from non-electrified households. Furthermore, they participated much more in decision-making of their household. Due to improved lighting in the evening women in electrified households showed higher mobility. They moved around the village in the evening, visited neighbours or went to the market (HALIM 2005: 3-8).

WAMUKONYA et al. (1999: 4) pointed out that access to electricity was highly dependent on income levels of the respective households. Households with grid access had on average around 25% more income than non-electrified households. Grid electricity was not affordable to all community members as the initial connection costs such as for wiring were rather high.

Gaining access to electricity and its direct benefits seems to be highly dependent on income levels, as initial as well as running costs in many cases exceed financial resources of poorer households. Wealthier households seem to be favoured by rural electrification programmes, as they are the first to benefit from impacts directly related with household access. However, it should be noted that the analysed studies mainly focused on benefits from electric household connections. Indirect impacts of electricity, e.g. through improved health facilities (cp. section 3.2.6) or schools (cp. section 3.2.5), that could also affect households without an own connection, have not been taken into account. Many studies identified women and children as the main beneficiaries in electrified households. As women and children spent most of their time within household premises, they benefited most from electric lighting and household appliances. Through improved media access, women can broaden their general knowledge base as well as gain information on specific gender-related issues such as women's rights. Improved labour options for women due to electrified industries were stated for the case of Bangladesh.

3.3 Critical remarks on applied methodologies

While analysing the impact studies on rural electrification it became apparent, that advocates of rural electrification in certain cases obviously confused causes and effects of electrification programmes. Correlations between the availability of electricity and household income or other indicators of social welfare such as education and health were sometimes taken as a proof for the positive economic impact of electricity on improved living conditions of electricity users (cp. BARKAT et al. 2002). However, in reality the situation might turn out to be different. FOLEY (1990: 94) for example stated that it might be the presence of factors such as wealth, economic dynamism, and literacy that facilitated the successful implementation of rural electrification programmes. He cited several studies that conclude that rural electrification only succeeded in areas where the necessary economic and social conditions were already present. In these favoured areas, there is e.g. enough financial power available for people and businesses to afford an electricity connection and invest in electricity-related businesses (FOLEY 1990: 94). Therefore, correlations between the availability of electricity and socio-economic indicators might just reflect disparities between households or villages, which were already present before electrification. These disparities might be the original cause for the unequal dissemination of electricity connections. For example, differences in average household income of electrified and non-electrified households might be caused by the high initial cost of electricity connections hindering poorer households to gain access. Although this interrelation seems to be obvious, correlations are still used to prove the positive effects of electrification. This is especially obvious in the study of Barkat et al. (2002), whose correlation between the HDI and electricity use has just recently been reproduced in a publication by the internationally accredited Global Network on Energy for Sustainable Development (GNESD) (GNESD 2007: 20). Results of impact studies should always be critically assessed regarding the causalities of interrelations.

Even though there are many indications for positive effects caused by rural electrification, some analysts argue that there is little evidence that any of the positive developments found in electrified areas are directly related to rural electrification. Several studies in the past therefore revealed very limited or no positive impacts from rural electrification programmes (cp. FOLEY 1990: 92-93). In fact, it seems to be extremely difficult to prove positive socio-economic changes as being directly and uniquely a result of rural electrification measures. This is especially true when taking into account the complexity of development processes and for many cases the lack of available data (FOLEY 1990: 92-93).

Some of the results from the studies analysed in chapter 3 constitute significant evidence that electricity did have positive impacts on development processes in rural areas. Nonetheless, drawing universally valid conclusions seems to be difficult as the social, economic, and political background differs significantly for the analysed country cases. Therefore, it is important to focus on the individual context of a country or region when trying to predict the impacts of electrification programmes.

4 Solar Home Systems in Rural Bangladesh

With a total area of 144,000 km^2 and a population of about 147 million, Bangladesh is among the world's most densely populated countries. More than 75% of the Bangladeshi population live in rural areas (CIA 2007, EIU 2007: 14). The state of human development is low. Since 1974, Bangladesh belongs to the group of 50 least developed countries identified by the United Nations on criteria such as low-income, human resource weakness and economic vulnerability (UN-OHRLLS n.d.). With a HDI of 0.530, Bangladesh ranks 137 out of 177 countries (UNDP 2006b). Please refer to appendices A1 and A2 for a map and additional detailed background information on Bangladesh.

A 2005 investment climate assessment by the World Bank identified poor-quality and poorly managed infrastructure, including insufficient electricity supply, as one of the major deficiencies in Bangladesh's investment climate (EIU 2007: 18-21). With an average energy consumption of about 200 kg Oil Equivalent per capita, Bangladesh ranks at the lower end of worldwide energy consumption (UL-ISLAM 2004: 9). Rural electrification was one of the first approaches of the Bangladeshi government to improve the rural energy situation and therewith facilitate sustainable development and poverty reduction. Besides the extension of the national grid, other approaches of electricity supply, such as decentralised electrification with SHS, have been promoted recently.

Before presenting in chapter 5 the results of an impact study of SHS dissemination in Bangladesh, this chapter will focus on the framework conditions for rural PV electrification, as well as ongoing programmes and respective approaches to bring electricity to rural areas. Section 4.1 will focus on the overall setting for rural electricity supply in Bangladesh. The approach of decentralised rural electrification with photovoltaic home systems will be described in general as well as for the Bangladeshi dissemination programmes in section 4.2.

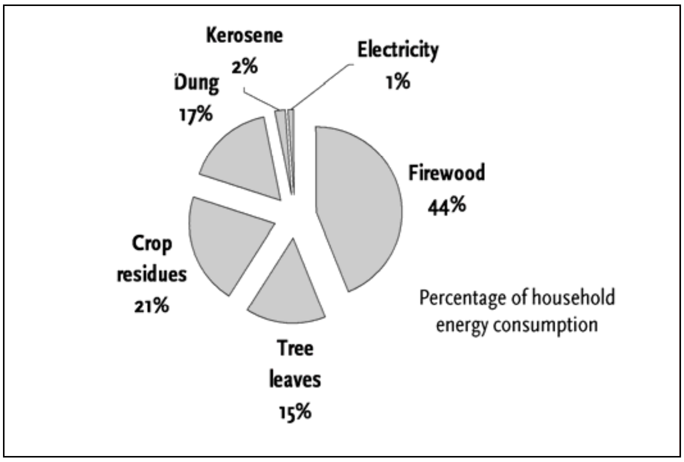
4.1 Energy situation and electricity supply in rural Bangladesh

The following paragraphs will describe the framework conditions for rural energy supply in Bangladesh. It will reveal details about rural Bangladesh's energy situation (section 4.1.1), the government's ongoing rural electrification programme (section 4.1.2), as well as the potential of RETs in rural electricity supply (section 4.1.3).

4.1.1 Energy in rural areas

Rural household energy consumption in Bangladesh is mainly dominated by the use of biomass (see Figure 5). Firewood is the most important source of energy, accounting for about 44% of total energy consumption. Together with leaves and twigs, tree-based biomass is pushed to a share of almost 60%. Crop residues such as bagasse, jute sticks, rice hulls and bran, as well as other kinds of uprooted remains of plants constitute another major source of rural energy with a share of about 21%. Animal residues such as cow dung are also frequently in use. In comparison to overall energy consumption, the use of modern energy sources such as electricity is insignificant. Only kerosene is used to some extent (ASADUZZAMAN 2006: 12).

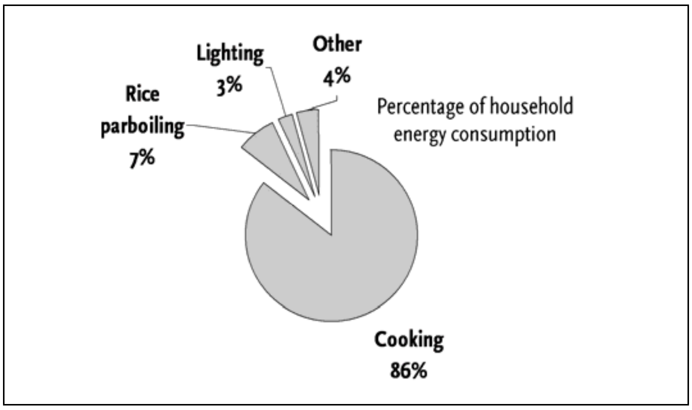
Figure 5: Pattern of energy consumption in rural Bangladeshi households



Data: Asaduzzaman 2006: 12; illustration: Michael Blunck

In rural Bangladeshi households, much of this energy is used for cooking and rice parboiling. Firewood, tree leaves, crop residues, and cow dung are used for cooking purposes, whereas kerosene and electricity are hardly ever used for cooking. Nonetheless, kerosene and electricity are the main energy sources for household illumination (ASADUZZAMAN 2006: 13). In 1991, kerosene accounted for more than 90% of the energy used for lighting (Bangladesh Bureau of Statistics 2004: 54). Due to rural electrification measures, this figure dropped to 70%, with the remaining 30% of lighting energy provided by electricity. However, compared to overall energy consumption, the fraction used for lighting is relatively small (see Figure 6). Another frequent use of electricity is for driving fans (space cooling) (ASADUZZAMAN 2006: 13-15).

Figure 6: Purposes of energy use in rural Bangladeshi households



Data: Asaduzzaman 2006: 12; illustration: Michael Blunck

Beside energy use in households, agriculture is the second major consumer of energy. Energy is mainly used for land tillage with diesel tillers and tractors, mechanised irrigation, as well as for the threshing and husking of rice. The area under mechanised agriculture is steadily increasing with currently 66% of cultivated land under mechanised tillage and 68% under mechanised irrigation. Almost 70% of villages use diesel pumps for irrigation purposes, whereas 10% use electricity (ASADUZZAMAN 2006: 15-18).

Rural enterprises are still highly biomass-dependent, one reason being the apparent low cost of biomass and the ease of availability. However, the use of kerosene and electricity for lighting purposes is prevalent. The biggest commercial consumer of energy is the service sector, accounting for nearly half of the total energy consumption in rural enterprises, whereas the manufacturing sector accounts for only 27% (ASADUZZAMAN 2006: 59-60, 73-74).

Biomass is mainly acquired from households' agricultural production, collection, or is purchased from the market. Recently the market has become an important source for biomass, mainly for firewood and dung, especially in periurban areas. Overall, nearly 40% of firewood and 23% of dung is purchased from the market, whereas the rest is gathered or comes from own agricultural production. Tree leaves are generally gathered while crop residues are mainly obtained from own production (ASADUZZAMAN 2006: 20). All modern energy carriers such as electricity, kerosene, diesel, and the like are supplied through the market. The national grid is thereby the biggest supplier of electricity providing more than 99% of electric power (ASADUZZAMAN 2006: 14). However, up to now only about 10% of rural households had formal electricity connections to the grid. The government of Bangladesh has undertaken approaches to increase the number of rural electricity connections and therewith improve the availability of electric power for households, agriculture, and enterprises through rural electrification programmes (ISLAM 2003: 139).

Recapitulating, energy consumption patterns in rural Bangladesh are dominated by the use of biomass for cooking purposes. Other cooking fuels are hardly ever in use. As only 30% of energy for lighting is obtained from electricity, kerosene still dominates for illumination purposes. The use of diesel and electricity for agricultural purposes is becoming more and more popular. Rural enterprises are still highly biomass-dominated, although the use of electricity - where available - is becoming more and more popular.

4.1.2 National electricity supply and the rural electrification programme

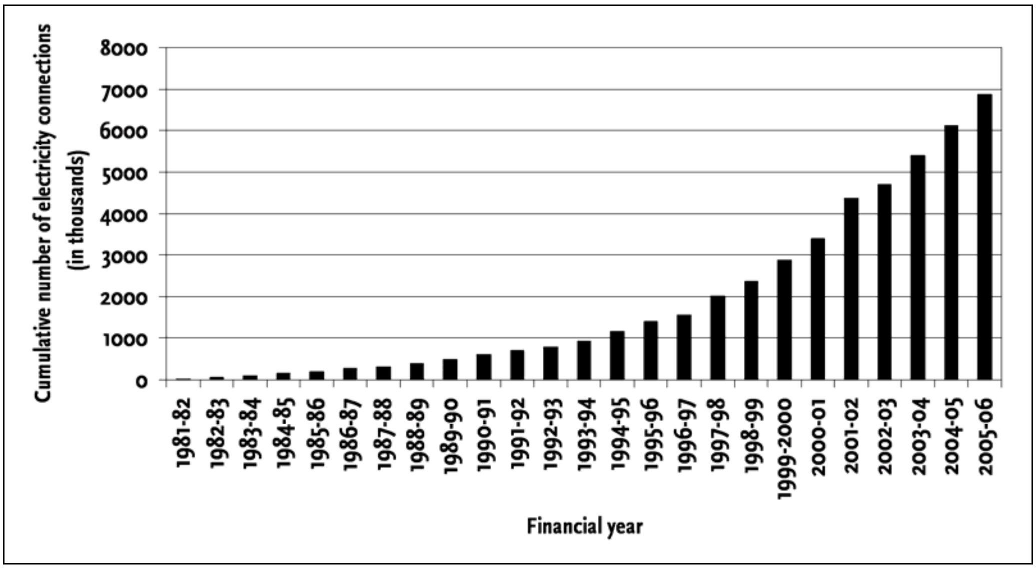
Bangladesh holds big reserves of natural gas, which are thought to be sufficient to meet domestic energy demand for the next 30 to 50 years. Natural gas meets about 70% of the country's total commercial energy consumption. Other energy sources include oil (25%), coal (4%), and a small amount of hydro power (< 1%). 90% of the electricity generated in the country comes from gas-fired power plants (IMAM 2005: 9-11). Electricity generation per head, however, is among the lowest in the world at about 158 kWh per year. The current generating capacity of 4,120 MW is not sufficient to cover countrywide demand, especially in the summer months. Shortfall of generating capacity is estimated to be 2,500 MW in the next four years (EIU 2007: 21). Bangladesh is the third lowest country in terms of per capita electrical consumption (MIYAN et al. 2004: 21). Approximately 85% of households do not have access to electricity. Overall system losses are as high as 30% of the total amount of generated electricity (EIU 2007: 21). Other problems faced by the electricity sector are huge amounts of load shedding and voltage variation, operating inefficiencies, poor bill collection, and thereby high financial losses (MURPHY et al. 2002: 21). The huge unmet commercial demand for energy and the lack of reliable sources of electricity are some of the most important factors deterring foreign investment and holding back economic growth (EIU 2007: 21).

In 1971, the year of Bangladeshi independence from Pakistan, only 250 out of 87,928 villages had access to electricity (BARKAT 2004: 2). From its formation in 1972, the 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). The Bangladesh Power Development Board (BPDB) was formed to operate and expand the electricity network of former East Pakistan Water and Power Development Authority, which had mainly concentrated on electrification of urban centres. After BPDP was assigned the responsibility of managing rural electrification, it soon became apparent that the programme would become too large for BPDP to manage effectively. The National Rural Electric Cooperative Association (NRECA), financed by USAID, was therefore commissioned to conduct a study on alternatives for a national rural electrification programme. NRECA developed a master plan, which was closely modelled after the U.S. rural electrification programme of the 1930s, and which included the formation of 72 rural electric cooperatives (RECs). The cooperatives would be financed and supervised by a semi-autonomous government body, which would establish the electricity distribution infrastructure to enable all rural inhabitants to avail access to the national power grid. Emphasis was put on the provision of electricity for agricultural mechanisation, irrigation, and rural industries (BARNES 2005: 83).

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). The REB was implemented as an agency of Energy and Hydrocarbons. It is responsible for planning and implementing all investments in rural electrification infrastructure as well as overseeing REC's performance and regulating prices. One of the main responsibilities of REB is to manage loans and grants provided by International Donor Agencies. With 16 International Donors and the GOB participating in the funding of the REB programme, tremendous coordination and collaboration has been achieved. Subsidies, which in general are common in rural electrification activities, have been directed towards making the rural electric cooperatives financially viable and enabling rural customers with low incomes to obtain connections (BARNES 2005: 85, 99-101).

In the beginning, REB was financed by USAID aiming at developing the capacity of REB to manage the programme and establish the first 13 RECs, locally known as Palli Bidyut Samities (PBSs). In the following years, more PBSs were put into operation, reaching an overall number of 70 today. By December 2006, 46,523 villages, corresponding to 54% of the total number of villages, had been electrified through the REB programme serving more than 7 million rural consumers (see Figure 7). The total rural distribution line more than doubled since 1999 to more than 200,000 km, covering most parts of Bangladesh. Service connections continue to increase at an annual rate of nearly 500,000 (BARNES 2005: 84, REB 2006). The REB is now responsible for nearly one quarter of all power distribution in the country (MIYAN 2004: 42).

Figure 7: Cumulative number of rural electricity connections in Bangladesh



Data: REB 2006b; illustration: Michael Blunck

The REB has set a goal to bring all villages of Bangladesh under electrification by 2020. The number of PBSs is further planned to rise to 75 in the final stage of countrywide electrification (REB 2006a). 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 constitutes a problem for a 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).

As there are remote areas and islands where supply of electricity from the grid is either very expensive or impossible, REB started implementing pilot projects based on the use of decentralised electrification with RETs in 1993. These projects focused on the dissemination of solar PV technologies and were later expanded into large-scale SHS dissemination programmes (REB 2005). Chapter 4.2 will reveal more information on respective SHS activities.

4.1.3 The role of renewable energy sources for rural electricity supply

Electrification of Bangladesh's rural areas by extending the national grid has been a slow and costly process. A mile of electricity distribution line presently costs around US$ 10,000 and takes an average rural consumer density of about 20 per mile, leading to an average cost of US$ 500 per consumer on account of distribution line costs alone. In more remote areas, distribution line costs may even well exceed US$ 1,000 per consumer (ISLAM 2004: 10). Especially for the case of Bangladesh with its landscape dominated by extensive areas of water, regular flooding, and certain regions such as river islands only accessible by boat, decentralised electricity supply with RETs might represent a serious and cost-effective alternative to conventional grid-based electrification measures. With its natural gas reserves estimated to be exhausted within this century and Bangladesh's petroleum consumption being totally import-based, the increased use of renewable energies 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. As most of Bangladesh is occupied by deltaic and alluvial plain land, most rivers are unsuitable for conventional hydroelectric plants. Only in the south-eastern part of the country, namely the Chittagong Hill Tracts, can some major rivers flowing through hilly terrain be found. This is where the only hydroelectric plant of Bangladesh, Karnafuli power plant, is situated. It has a total generating capacity of 230 MW, 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 effects creating long drawn social unrest among the local populace. Due to the continuous unstable political situation in this part of the country, many experts advise not to consider the construction of any further hydroelectric plants (IMAM 2005: 252-253). MIYAN et al. (2004: 30) state that there might be some potential for small-scale hydropower from "run of the river" turbines that do not require reservoir dams. However, to date no significant developments regarding small-scale use of hydropower for rural electrification purposes has been observed.

The use of solar photovoltaic technology is probably the most developed option for rural electrification with renewable energy sources. 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). Installation of small scale PV electrification systems has been taking place in the country over the last decade, initially for signalling lights on watch towers, refrigeration in hospitals etc., and then on a larger scale in the form of SHSs in remote rural areas away from the national electric grid (IMAM 2005: 254). Experience has revealed that PV electricity seems to be most appropriate for isolated rural areas away from conventional gridlines (ISLAM 2005: 79). With an installed capacity of about 850 kW in 2004 and ever since continuously growing numbers, the SHSs are by far the most widely disseminated RET in Bangladesh (ISLAM 2004: 18). A study conducted by the World Bank in 1998 revealed a market size of 0.5 million households for solar electrification in Bangladesh, with a potential of extending to 4 million in the future (KHAN et al. 1998: 12). ISLAM (2005: 81) revealed a short to mid-term market potential of about 60 MW of PV systems. He 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). Big potentials are also credited to the use of PV technology for irrigation purposes (PV water pumping), although experiences are still only available from single pilot projects (ISLAM 2004: 19-20). Further information on the SHS technology as well as respective dissemination programmes in Bangladesh will be presented in paragraph 4.2.

In contrast to India, which is by now the world's third largest wind power market, the potential for electricity generation from wind power is more limited in Bangladesh. Wind speeds highly vary between different times of the year as well as different regions of the country. Several studies and pilot projects revealed that between November and February there is practically no usable wind speed available. Overall, only 30% of the time are wind speeds sufficient to drive wind turbines. Therefore, wind turbines have to be integrated with photovoltaic, diesel or biomass technology for continuous operation and system reliability. Currently, apart from small pilot projects there is no large-scale dissemination of these hybrid systems observable (ALAMGIR: 3-4, ISLAM: 2004: 30). The countrywide wind power generation capacity is only about 50 kW, representing 0.001% of Bangladesh's power capacity (MIYAN et al. 2004: 32). It will take much more practical experience and effort in research to bring the wind sector out of this early stage of development. The main challenge that remains is the financial viability due to the relative high construction costs of wind turbines capable of withstanding the forces associated with cyclones regularly occurring in the Gulf of Bengal (MIYAN et al. 2004: 32).

With 20 million cattle producing about 220 million kg of dung each day, Bangladesh has huge potential for biogas production (IMAM 2005: 249). Apart from the use of cow dung, first experiences with small biogas plants attached to rural poultry farms have proven quite successful in the past. However, biogas is used in nearly all cases for cooking purposes. Examples from India reveal that rice-husk based biomass gasifiers coupled with small gas engine generator-sets can be quite successfully operated to generate and supply electricity for the requirements of rice mills and other rural applications. First approaches to generate electricity from biomass such as animal waste or crop residues are still in the early stage of development and testing. However, for the future there might be an enormous application potential for these technologies (ISLAM 2004: 30).

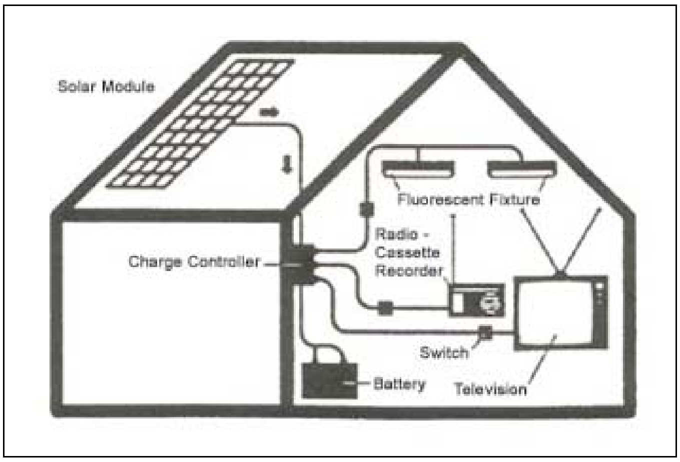
4.2 The Solar Home System electrification approach

As sections 2.3 and 4.1 already implied, solar PV technology is highly relevant for decentralised rural electricity supply in developing countries in general and Bangladesh in particular. Due to the proximity to the equator, insolation in most developing regions of the world is sufficient for PV use. 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. This section will describe technical aspects of SHSs (section 4.2.1) as well as its evolution from the use in small isolated pilot projects to successful large-scale dissemination programmes (section 4.2.2). Section 4.2.3 will focus on current SHS dissemination programmes in Bangladesh and describe respective implementation approaches.

4.2.1 Technical background

SHSs convert solar energy to electricity using solar cells, and therewith charge lead-acid batteries. The battery in turn powers lights and appliances in the household. Figure 8 displays the main components of a conventional SHS.

Figure 8: Typical Solar Home System components



Source: Hankins 1993: 10

The photovoltaic/solar module (see Figure 9) converts the sunlight into electricity. It typically has a capacity of between 20 to 100 Wp. The solar cells are in most cases manufactured in developed countries. However, a number of developing countries manufacture modules from imported solar cells (CABRAAL et al. 1996: 7, HANKINS

1993: 10). 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. Typical SHSs operate at 12 volts direct current (DC) and use efficient fluorescent or LED lamps and appliances to make best use of the provided power (HANKINS 1993: 10). A typical 50 Wp 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. While DC black-and-white televisions, radios, and some other small appliances are generally available, other DC appliances are not so widely offered or cost more than their alternating current (AC) equivalents (CABRAAL et al. 1996: 15).

Figure 9: House with solar panel, Bangladesh

Photograph: Michael Blunck

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, and servicing, and the cost of funds for working capital and capital costs (CABRAAL et al. 1996: 8-9). Reducing the market prices of SHSs by influencing the above factors is an important strategy of many SHS dissemination programmes. For this purpose, local manufacturing of SHS components is a common approach in many developing countries (CABRAAL et al. 1996: 10-12, HANKINS 1993: 10).

4.2.2 Progression of worldwide Solar Home System dissemination

The first interest in solar technologies for rural stand-alone electrification arose in the 1970s. Isolated projects experimented with medium-size PV systems for purposes such as water pumping and electrification of community centres. Most projects focused on testing technologies and demonstrating the potential of solar PV technologies. Therefore, activities frequently ignored real local needs and conditions. Many projects failed due to ignoring the necessity for local technical training and maintenance service, user education, and awareness programmes. In most cases, a sense of local ownership or responsibility for the solar projects did not develop, as they were fully financed by donors with no financial commitment for the beneficiaries involved. This period, however, provided important lessons for solar projects that were implemented later on. The results of these early approaches proved that local participation, particularly in the form of financial involvement, was essential in the success of technology dissemination (CAMPEN et al. 2000: 5-6).

Assisted by a significant decrease in the production costs of solar panels, the 1980s were characterised by the development of new approaches to introducing small solar systems on a more sustainable basis. Analysis of rural household energy demand and spending power provided the base for NGOs and grassroots groups to initiate these new approaches. Surveys revealed that households were used to spend 5 to 15% of their monthly budget on energy sources for lighting and audiovisuals such as candles, flashlights, kerosene lamps, or car batteries. Pilot projects proved that SHSs could provide a higher quality and more reliable energy supply as long as the households' monthly energy budget could be used to serve a credit scheme or leasing plan. Learning from the 1970s' experience, the new approaches included the support of a local service infrastructure, with capacity building and training of local technicians, introduction of fee collection mechanisms and user education. These NGO-driven pilot projects were replicated in several countries with varying degrees of success. For instance, by the end of the 1980s, the Solar Electric Light Fund (SELF) had established pilot projects in over ten countries. Beside NGOs, local PV dealers were the second driving force of small-scale SHS commercialisation. They mainly targeted the 5 to 10% of most affluent rural families, as they generally did not offer consumer credit schemes. However, in certain cases credit and low cost maintenance services were even introduced by private PV dealers. For instance, this approach was successfully implemented in the 1980s in Sri Lanka, Kenya, and Zimbabwe (CAMPEN et al. 2000: 6).

By the mid-90s, various initiatives were launched to scale up into large SHS commercialisation and government-sponsored dissemination programmes, harnessing the lessons learnt from the 1970s and 1980s. CAMPEN et al (2000: 6-7) summarise the lessons learnt as follows:

- Assessment of energy needs and present energy expenses has to be the basis for project design.
- Rural credit models and effective fee-collection mechanisms have to be established.
- Infrastructure for distribution, installation, maintenance and repair of PV systems has to be in place.
- Solar technicians have to be trained; capacity building for solar dealers/micro enterprises has to be conducted.

With these lessons in mind, SHS projects multiplied rapidly. By the end of 2005, 2.4 million SHSs had been installed worldwide with an estimated annual installation of more than 270,000 systems (REN 21 2006: 12). As the size of the potential rural PV market became evident, a shift to a fully commercial era for SHSs was observable. For instance, some of the most prominent practitioners from the NGO sector started profit ventures, attracting private investor capital. In some countries such as Argentina, Mexico, China, India, Morocco, and South Africa, SHS programmes were initiated and carried out by the public sector with a subsidised approach and some private sector involvement at the implementation level. During the last decade, PV rural electrification also triggered the development of other standardised solar PV applications for communal use, such as vaccine refrigeration units in rural clinics, lighting sets for rural schools, water pumps, and street lighting (CAMPEN et al. 2000: 7-8).

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. Of the 270,000 SHSs added worldwide in 2005, 120,000 were added in China, 90,000 in Thailand and more than 20,000 were added in India, Sri Lanka and Bangladesh respectively. In these countries, the problem of affordability has been overcome either with micro-credit or by selling small systems for cash. Furthermore, governments as well as International Donor Programs have supported markets. SHS sales will probably further increase within the next decade. China, for instance, has just finished its Township Electrification Programme in 2005 after having electrified about 200,000 households with solar PV, small hydro and wind power. Plans are already prepared for the next programme, focusing on the electrification of 3.5 million households with renewable energy technologies by 2010, including up to 270 MW of solar PV (REN21 2006: 11-12, REN21 2005: 31).

4.2.3 Solar Home System dissemination in Bangladesh

The first experience with SHSs 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 SHSs belonged to the REB, while the users had to pay an initial security deposit and monthly fixed tariffs for the use of the system. As the user was not the owner of the system, REB was responsible for installation, maintenance, repair, and replacement of the SHS components. Appliances such as lamps and TVs belonged to the users (EUSUF 2005: 55). The project proved the technical feasibility and socio-economic acceptability of SHSs 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).

Follow-up activities by the REB to disseminate more SHSs, however, have been “extremely slow” (ISLAM 2004: 19). Two parallel programmes using the ‘fee for service’ model started in 2002. The programme ‘Diffusion of Renewable Energy Technologies’ focuses on remote locations of selected districts with a final target of 6,000 disseminated SHSs. However, as of April 2006 only 605 SHSs had been installed. The project was funded by the Government of Bangladesh (GOB) without any commitments of foreign donor agencies. The second programme, ‘Rural Electrification through Solar

Energy', is funded by the World Bank. Its target was to install 16,000 SHSs by 2007. As of April 2006 only 694 systems had been disseminated (REB 2005, REB 2006c).

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 SHSs were 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 SHSs by following 'cash sale' and 'credit sale' approaches. GS offers different financing options of which all lead to complete system ownership for the customer:

- The user has to pay 15% of the total system price as down payment. The remaining 85% of the cost is to be repaid within 36 months with a 5% to 6% service charge depending on mode of payment ('credit sale');
- The user has to pay 25% of the total system price as down payment. The remaining 75% of the cost is to be repaid within 24 months with a 4% service charge ('credit sale');
- The user pays the total amount in cash and receives a 4% discount ('cash sale') (BARUA 2005: 9).

The first financing scheme was used in the early implementation stage and later complemented with the latter two approaches. Free after-sale service is guaranteed for three years, with regular maintenance service provided by GS staff during their visits to collect the monthly instalments. After the three years of free service, after-sale service is provided for a minimal fee of about US$ 5 per year (BARUA 2005: 6). As of September 2002, about 10,275 SHSs with a total capacity of 0.5 MW had been installed by GS in various remote areas of the country. The number of annually sold SHSs by GS increased from 375 in 1998 to 3,196 in 2001, indicating high popularity of both the system and the respective marketing approach (IMAM 2005: 255).

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), the German Kreditanstalt für Wiederaufbau (KfW) and German Technical Cooperation (GTZ). The

Infrastructure Development Company Limited (IDCOL), a government-owned entity, disseminates SHSs through 16 participating organisations (POs), namely experienced NGOs such as GS or the Bangladesh Rural Advancement Committee (BRAC) (together disseminating more than 85% of the overall number of SHSs) as well as a number of smaller NGOs and private enterprises. The POs sell the SHSs to households and small businesses mostly through 'cash sale' and micro credit schemes comparable to the one of GS (see above). 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 2006). As IDCOL's primary objective is the commercialisation of SHSs, the amount of grants was gradually reduced during the last years from US$ 90 per system in 2002 to currently US$ 50 per system. US$ 40 of this money is used to reduce the selling price of the SHSs (US$ 375 for a 50 Wp system), while US$ 10 per system is used for institutional development purposes of the POs (KAMAL 2004, ISLAM et al. 2003: 139). 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). IDCOL's initial target was to disseminate 50,000 SHSs by the end of June 2008. However, due to unexpected high SHS sales this target had already been achieved in September 2005, three years ahead of schedule and US$ 2 million below estimated project costs. As the popularity of SHSs continues, IDCOL set a new target of 200,000 SHSs to be sold by 2009. With more than 100,000 SHSs sold by January 2007, the IDCOL programme is one of the fastest growing renewable energy programmes in the world (IDCOL 2006, IDCOL 2007).

5 Impacts of Solar Home Systems in Rural Bangladesh

Recent electrification programmes increasingly use RETs for decentralised electricity supply. Depending on the technology in use, it is very likely that the impacts vary from centralised grid-based approaches. Especially technologies like stand-alone solar photovoltaics provide much smaller loads compared to grid or mini-grid connections. Thus, the use of electric appliances as an important factor for potential positive impact might be severely limited.

When it comes to the impacts of decentralised electrification with Solar Home Systems, broad studies are by far not as numerous as for grid-based approaches. CAMPEN et al. (2000: 16-22) summarised some results of existing work in this field, which will be used as reference when discussing the results of the following case study from Bangladesh. One of his findings is the fact that evidence of direct impacts from SHSs varies significantly, depending on respective country cases.

To find empirical evidence of the impacts caused by SHSs in Bangladesh, a broad study was conducted by the author of this thesis in 2006 aiming at identifying the most relevant socio-economic impacts for SHS users as well as non-electrified households. Data was collected from various sources such as a household survey and interviews with local experts involved in the SHS dissemination process. The findings of this empirical work led to the formulation of recommendations to amplify benefits and minimise the negative impacts of SHS electrification in rural areas of Bangladesh.

After describing the scientific methods (section 5.1), some general information on household characteristics as well as the role of electricity in the context of households' problems of daily life will be given (section 5.2). In section 5.3, the households' current purposes of energy use will be analysed, thereby focusing on traditional energy sources as well as electricity supply. The detailed analysis of socio-economic impacts attributed to the dissemination of SHSs will be presented in section 5.4, followed by a brief overview on potential ecological impacts (section 5.5). From the prior findings, the author will derive recommendations for ongoing SHS dissemination programmes in section 5.6.

5.1 Methodology

In contrast to several previous studies on electricity and respective impacts (cp. chapter 3), emphasis was put on the accountability of socio-economic change to the provision of electricity access. Therefore, a mixture of qualitative and quantitative methodological approaches was applied, giving explanatory information regarding electricity's influence on the quantifiable socio-economic data. Qualitative interviews with experts involved in the SHS dissemination process provided general information regarding the SHS programmes and revealed the experts' subjective opinion regarding socio-economic impacts of solar electricity. To complete this information with field-level data, an extensive household survey and individual short interviews with shop-keepers and owners of small businesses were conducted in three villages.[4] The following sections will present the respective methodological approaches in more detail.

5.1.1 Qualitative interviews with SHS experts

Detailed qualitative interviews with experts in the field of SHS dissemination were conducted between September 4, 2006 and September 19, 2006. All interviewees were involved in the SHS dissemination process and had gained sufficient experience from the field to give a professional impression regarding impacts of SHS use in rural areas. The group of interviewees included representatives of the seven major organisations directly involved in SHS dissemination, i.e. IDCOL, four SHS disseminating NGOs, the REB, and Rahimafrooz, Bangladesh's biggest manufacturer of batteries and producer of SHS components. Furthermore, two scientists, who had conducted SHS-related research before, were included as additional sources of information. Appendix A3 specifies the nine interview partners as well as their role and position in the SHS context.

Guideline questions (see appendix A4) were used to make the respective interviews comparable. After gathering some general information on the interviewee and his opinion of certain development issues in Bangladesh, the questions focused on the

[4] It was originally planned to include for this study, interviews with social institutions such as schools and clinics. However, due to limited time, and the virtual non-existence of SHS-powered schools or clinics in the study area, interviews in respective social institutions were not carried out.

social and economic impacts of SHS use for rural households and social institutions, such as schools and health facilities. Another focal point was put on the productive use of the provided electricity. The last block of questions focused on issues regarding the sustainability and future of SHS dissemination. The duration time of the interviews was in general about 50 minutes. The interviews were recorded and transliterated for further analysis. Not all the data gathered through the interviews will be presented in this paper, as not all questions were meant to provide information for the current research objective. However, the gathered information served as a basis for the design of the household survey questionnaires.

5.1.2 Household Survey

To reveal quantitative as well as qualitative information from users and non-users of SHSs, empirical household-level data was collected through a household survey conducted in villages with ongoing SHS dissemination ('SHS villages') as well as one non-electrified village.

Overall, 178 interviews in rural households had been conducted between October 10 and October 19, 2006. Two types of structured questionnaires were used as the principal tool for data collection (see appendix A4-A5). The application of respective questionnaire types depended on whether households had any kind of electricity source (questionnaire 1), or not (questionnaire 2). Questionnaire types differed in length as most questions related to electricity use were left out in the second type. However, some additional questions, e.g. on general interest in electricity supply and respective affordability, were featured in questionnaire type 2. The questionnaires were characterised by the mixture of closed and open questions, allowing the collection of detailed quantitative as well as additional explanatory information.

The questionnaires were structured as follows:

- **Household structure**
  e.g. household size and composition
- **Problems of the household and general expectations**
  e.g. problems faced by the household in general and regarding village infrastructure, perception of living conditions
- **Economic situation**
  e.g. occupation, household income sources and expenditures

- **Energy for cooking**
  e.g. energy sources used for cooking purposes and respective expenditures, time use for fuelwood collection
- **Energy for lighting**
  e.g. energy sources used for lighting purposes and respective expenditures, kerosene-related accidents
- **Sources of electricity and expenditures**
  e.g. electricity sources and respective expenditures, preferred sources of electricity, general information on SHS acquisition
- **General use of electricity**
  e.g. electricity-consuming activities, appliance ownership and use, use of electricity by neighbouring non-electrified families
- **Appraisal of electricity and Solar Home Systems**
  e.g. benefits and disadvantages of electricity in general/from respective electricity sources, satisfaction with SHS, beneficiaries of SHS, interest in SHSs and alternative small systems
- **Productive activities in the household**
  e.g. income-generating activities and related income, use of electricity for productive purposes
- **Social life**
  e.g. time use, work load, children's studying, feeling of safety, TV and radio use, health issues, migration

As no baseline data of former surveys was available, respondents were requested to provide all information for the current situation as well as an estimate for the time before the advent of SHSs. This approach is often referred to as the Recall Method in social sciences. To gather comparable data for all interviewed villages, the elapsed time since the start of SHS dissemination in the respective villages had to be equal. This time frame was set to three years, as it still guaranteed somewhat reliable recollection of respondents. In addition, it represented a sufficient period for actual changes to take place. Furthermore, a non-electrified village was identified as a control group enabling the comparison between villages with and without ongoing SHS dissemination.

To identify SHS villages for the household survey the following criterion were applied:

- Medium size of village (about 400-500 households),
- ongoing SHS dissemination for about three years,
- electricity from the national grid is not available,
- income level of households is about average (not especially poor or wealthy).

First of all, the study area was selected. It was located in the Mawna region of Shripur District, about 50 km north of Dhaka city near the Dhaka-Mymensingh highway. The nearest medium-size town was Gazipur. With the help of local Grameen Shakti staff, two villages were identified for the survey, namely Goldapara (village A) and Vutulia (village B). Goldapara comprised of about 450 households of which 41 owned a SHS. The size of Vutulia was about 400 households with 10 SHSs sold up to the period of this research. Several field trips revealed that there were no villages without a grid line or SHSs existent in the area as there had been strong ongoing SHS dissemination activities by local NGOs. Therefore, the control group village had to be chosen from another district. Finally, the village of North Bakchar (village C) near Singair in Manikganj District was selected. As choices were limited, the size of the village (175 households) was smaller compared to the former two SHS villages.

For sampling three main household groups were identified stratifying the overall sample:

- Rural households with SHS (group 1),
- rural households without SHS in the two villages with SHS dissemination (group 2),
- rural households without SHS in the village without SHS dissemination (group 3).

For each stratum, a minimum size of 40 households was predefined. All 51 existing SHS households (group 1) were interviewed (full sample). Furthermore, for the case of SHS villages A and B, a random sample of overall 87 remaining households (group 2), equalling about 10% of the total remaining households was drawn. 40 households or about 23% of all households of village C (group 3) were interviewed as a control group. As sample fractions varied by stratum, data had to be adjusted using weight factors to correctly represent the population. Table 3 displays the detailed sampling scheme together with weights used for data analysis.

Data collection was conducted by a team of five local interviewers, all of them students and graduates from Dhaka with good practical experience in interviewing methods and techniques. They were supervised by an experienced team leader, who was responsible for quality control of the conducted interviews. Furthermore, the author attended several interview sessions to provide additional supervision and advice. Thus, a high standard of data collection could be provided. Due to the difference in length of respective questionnaire types, the average duration of interviews was about 90 minutes for households with electricity and 60-70 minutes for non-electrified households. The length of interviews was not seen as a significant hindrance as the interviewed household members showed great interest in the survey activities. As knowledge of English is very rare in rural Bangladesh, the interviewers translated the questions, as well as respective answers, on-site.

Table 3: Sampling plan and weight factors by household groups

Stratum	Number of interviewed households (n)			Sample size ($n_{stratum}/N_{stratum}$)	Weight factor
	Village A ($N_a = 450$)	Village B ($N_b = 400$)	Village C ($N_c = 175$)		
Group 1	41	10	-	100%	1
Group 2	47	40	-	~10%	10
Group 3	-	-	40	~ 23%	4.4

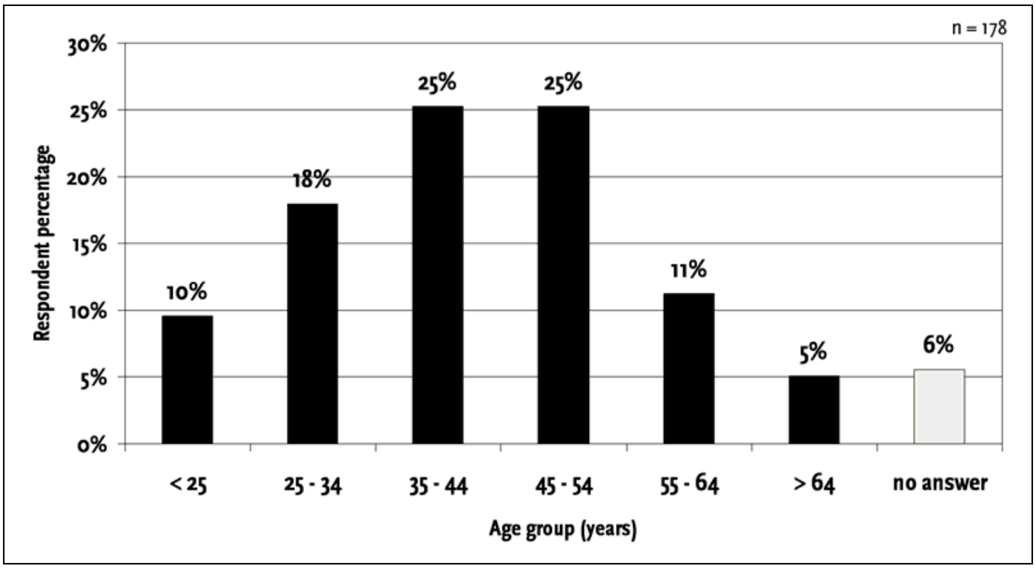
Group 1: Households with SHS
Group 2: Households without SHS - in village with active SHS dissemination
Group 3: Households without SHS - in village without SHS dissemination

N: Size of total population
n: Size of sample

After the first field tests, it became obvious that the gathering of income-related data seemed to be somehow problematic. Most households rejected to answer questions related to household income. Therefore, the questionnaire was adjusted to focus on households' monthly expenditures (E_M), savings (S_M), and loans (L_M). The monthly household income (I_M) was then roughly estimated by applying the formula $I_M = E_M + S_M - L_M$.

The interview partner selected for participation in the survey was mostly the household head (70% of cases) or the respective spouse (24% of cases). Only in 6% of cases due to the absence of both, household head and spouse, other household members had to be interviewed. Given the physical presence of both, male and female household members, men preferred answering the questions for the most part. Therefore, more male (73%) than female (27%) household members were interviewed. However, even in the case of male interviewees, women frequently participated in the answering of questions. In general, participation of other household members or neighbours was a common phenomenon. The age of respondents varied in the range of 16 and 86, equally covering all age groups (see Figure 10).

Figure 10: Respondents' age groups



Data: Household survey, 2006

Following data collection, the questionnaires were entered into the Statistical Package for Social Sciences 13 (SPSS 13). Answers to open questions were assigned to coded groups, enabling further quantitative analysis. After applying the respective weight factors (see Table 3) to the different household groups, statistical analysis was performed. For income-related analysis, households were assigned to three income groups each roughly representing one third of the total number of households: low-income (below 3500 BDT[5]/month), middle-income (3500 - 4999 BDT/month), and high-income (5000 BDT/month and more) households.

5.1.3 Short interviews with owners of shops and small businesses

To get a picture of the benefits of SHSs for shopkeepers and owners of small businesses, short interviews were conducted at the local bazaars in villages A and B. Using some guideline questions (see appendix A7) most interviews led into a short open discussion on the benefits of using SHSs for business purposes. As time was limited, only nine of these short interviews/discussions were conducted. These included interviews with six owners of shops/small businesses owning a SHS, as well as owners of three shops/businesses without electricity. Interviews were conducted with owners of a tea stall, some grocery and tailoring shops. As the sample was rather small, observations from these interviews should be interpreted with reservations and seen as a basis

[5] Bangladeshi Taka; as of May 28, 2007: 1 EUR = 93 BDT; 1 US$ = 69 BDT

for further research activities. General trends and opinions, however, became clear even from this limited number of observed cases.

5.2 General village and household characteristics

Before concentrating on energy issues and related socio-economic impacts, it is essential to draw a general picture of the situation and conditions within villages and households in focus of this investigation. The following paragraphs will present some basic information on the socio-economic context, problems and expectations of rural Bangladeshi households.

5.2.1 Overview on sample villages

Village A was the biggest of the surveyed villages with an estimated 450 households. With an average household size of 5.3, the approximate population of the village was around 2,400. The households were quite scattered over a large area dominated by rice and vegetable fields and small patches of tree cover. A primary school and local market were available. The next electric grid line was about 3 km away and there were no plans for the near future to get the village connected. SHS dissemination had started around three years ago, with 41 (8%) of all households owning a system at the time of this research.

Village B was slightly smaller with about 2,100 inhabitants in approximately 400 households. Households were also scattered, however, the village was more compact than village A. There was a school as well as a local market. The grid line was about 1 km away from the village. Up to the time of research only 10 (2.5%) of households were equipped with a SHS. This might be due to the potential advent of grid access within the near future. Some villagers noted that it might not take too long before the village would be connected.

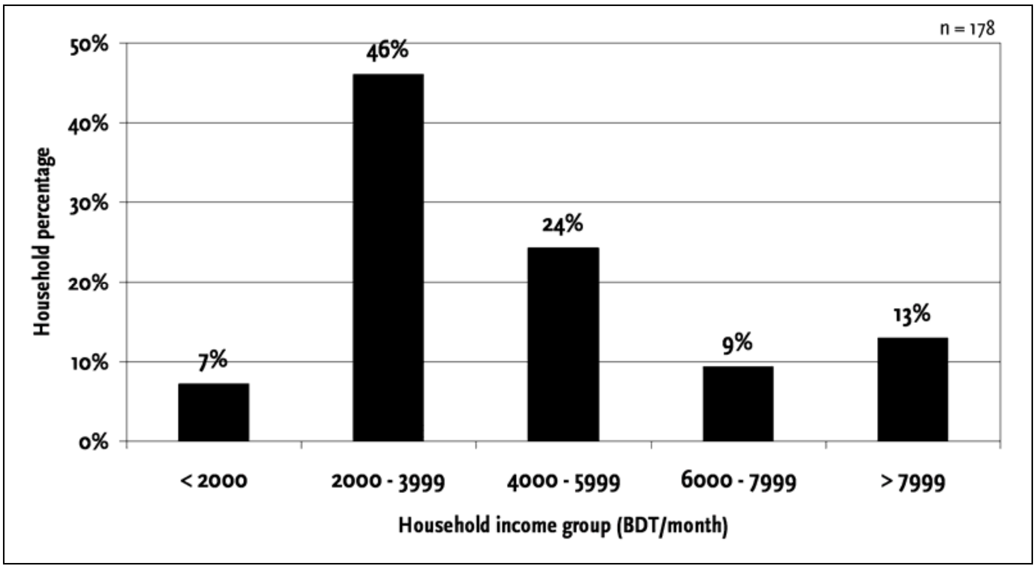
Village C, being smaller than the two other villages was made up of approximately 175 households with about 900 to 950 inhabitants. The village was very compact with not much space left between respective dwellings. Beside rice cultivation, sugar cane plantations were prevalent around the village. As in many other areas of Bangladesh, the water sources in village C were affected by arsenic contamination causing health problems among the village population. A school and market were available in neighbouring villages. The next grid line was only about 500 m away, however, despite promised from local political leaders no progress in further extension of the electric lines had been carried out in the last few years. As there was no SHS-disseminating organisation active in village C or the nearby villages, SHSs were virtually unknown and therefore not in use at all.

5.2.2 Household characteristics

The interviewed households' average size was 5.3 persons per household, nearly equalling the country average for rural areas of 5.2 persons per household (Bangladesh Bureau of Statistics 2004: 705). In 95% of all cases, there was a married household head (mostly male) with spouse, often with children and/or other family members, such as grandparents or uncles living in the same household. The household head and spouse had, on average, 3.3 children. The number of children attending school, madrasa (religious schools), or college was 1.3 per household. These figures notably depended on household income, with 3.8 children (1.5 schoolchildren) living in the wealthiest third of households, and only 2.9 children (1.2 schoolchildren) per household in the poorest third of households. Reflecting local marriage traditions, husbands were, on average, nearly ten years older than their wife was. Differences in educational levels of male and female household members were obvious with an average time of schooling of 3.7 years for men and 3.0 years for their respective wives. Very striking was the high educational level of male household heads in high-income households with an average of 5.5 years of schooling.

The average overall monthly household income was 4,700 BDT equalling 51 Euros / 68 US$. This value nearly resembles the average household income for the whole of rural Bangladesh, which is about 4,800 BDT (Bangladesh Bureau of Statistics 2004: 705). Therefore, it can be stated that the villages were neither extremely wealthy nor poor, and thus represented well the economic situation of an average rural community. To get a better impression of income reality for the rural households, income distribution has to be taken into account. The three villages were characterised by quite dispersed income distribution (see Figure 11).

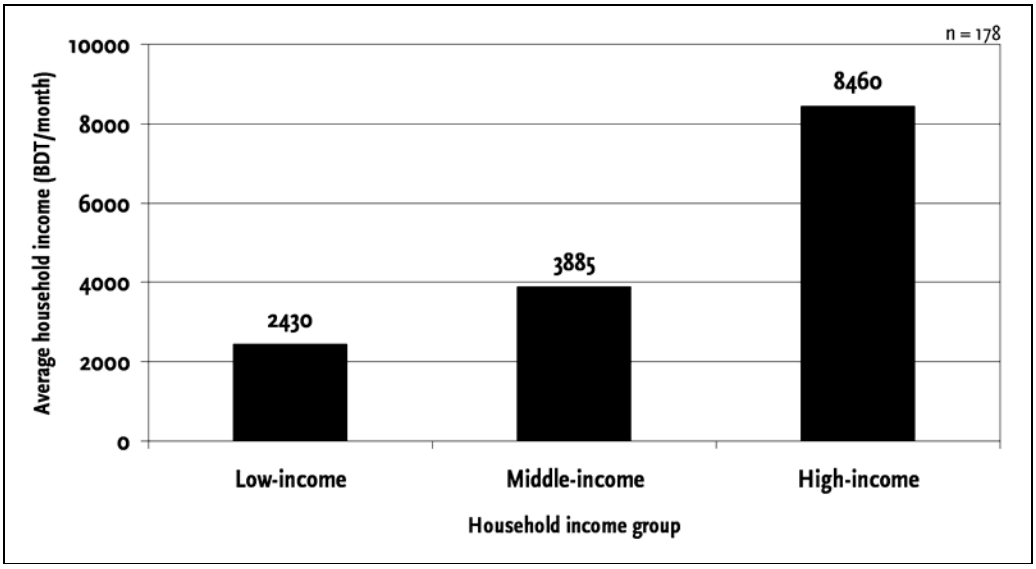
Figure 11: Distribution of households by income groups



Data: Household survey, 2006; strata weighted to represent total population (see section 5.1.2)

Nearly half of all households earned between 2,000 and less than 4,000 BDT per month. Furthermore, while on the one hand there were about 7% of extremely poor households earning less than 2,000 BDT per month, on the other hand 13% of households had monthly earnings of 8,000 BDT and more. Figure 12 depicts this income gap by stating the average household income for three equally sized income groups.

Figure 12: Average monthly household income by income group



Data: Household survey, 2006; strata weighted to represent total population (see section 5.1.2)

When being asked about their economic conditions of three years ago, nearly all households stated an increase in income due to improved economic conditions. The average increase in income during the last three years was about 30% per household.

However, this figure has to be put into perspective as it overlooks broad differences among the different income groups. Taking into account the respective growth rates for the three previously defined income groups, income growth of the last three years was highest for the wealthiest group of households (44% growth), moderate for middle-income households (22% growth), and extremely weak in the poorest third of households (6% growth). Economic development of the last years seems to have mainly benefited the households that had already been better off. The poorest households could not significantly increase their overall income over the last three years.

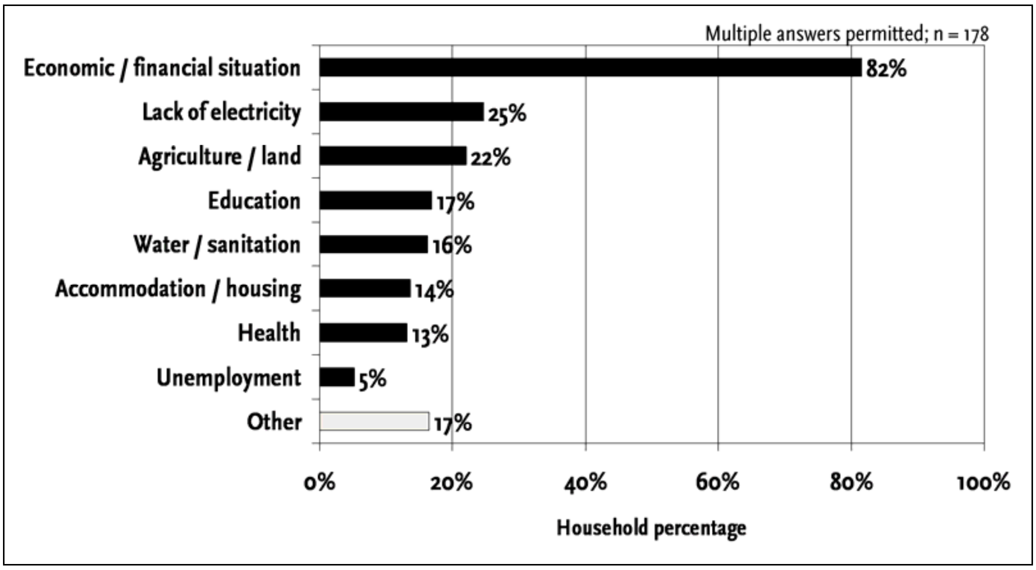
Agriculture, including crop cultivation, agricultural labour, and livestock represented the main source of income for most households, the main agricultural crops found in the area being rice and vegetables. Furthermore, poultry and fish farming were prevalent activities. Other economic activities included the trading of agricultural goods, the running of small business like shops and workshops, as well as the provision of services (e.g. teachers, rickshaw pullers, etc.). Although generally below 8% of households, the percentage of households with factory workers was, with 18%, quite high in village B, due to the proximity of a garments factory. The main income generating activities such as agriculture, business, or services were mainly conducted by adult male household members, while women's main activities were centred on household-related work. In a few cases, women were engaged in handicraft production or employed as workers in small local textile industries. Comparing between income groups, agricultural activity was more often stated to be the main source of income in wealthier households, which can be attributed to the higher land ownership among richer households. Furthermore, the percentage of households with income from an own business was more than double in the wealthiest third of households compared to the other income groups. Remittances from family members working abroad (mainly in the Middle East) were a third important source of income in richer households. Poor and middle-income households depended much more on seasonal and day labour, indicating much higher insecurity and irregularity of the households' income situation.

Micro finance activities are a common phenomenon in rural Bangladesh. Micro finance institutions such as the Grameen Bank, BRAC and many others provide small loans for investments of rural households and entrepreneurs. This was also the case in the surveyed villages, where 45% of all households had taken a loan from a local NGO or the government at the time of research. Most household loans ranged between 1,000 BDT and 20,000 BDT.

5.2.3 Problems and expectations of interviewed households

To identify the relevance of electricity supply in the context of Bangladeshi village life, households were requested to name the biggest problems they had to deal with in daily life (see Figure 13). 92% of all households stated that for at least one of their problems help from NGOs or the government would be necessary to find a solution. In these cases, respondents were requested to give ideas regarding potential interventions of the government or NGOs to help solving the respective problems.

Figure 13: "What are the main problems your household has to cope with?"



Data: Household survey, 2006; strata weighted to represent total population (see section 5.1.2)

By far the most frequently stated problem was the households' economic situation characterised by the lack of financial resources. Monetary poverty seemed to be an issue concerning households across-the-board. This aligns with the opinion of most SHS experts, frequently emphasising the low household income and lack of monetary resources as a key problem of rural Bangladeshi households. Across the board, respondents in the households suggested the provision of more credit and loan facilities to resolve this issue. In contrast, SHS experts mainly recommended the fostering of income possibilities and job creation.

Problems other than monetary issues were stated much less frequently on household level. Across the sample villages, about one quarter of households indicated the lack of electricity being a major problem. This figure was remarkable high for low-income households, of which one third of respondents found the absence of electricity to be problematic. Notably, 6% of households owning a SHS still stated electricity supply as a problem. However, these results should be judged with minor reservations, as households knew beforehand about the survey objective. Therefore, the probability of a household to state electricity as a problem might have been slightly higher. Still, electricity seemed to be an important issue for most households. As all interviewed SHS experts were involved in the energy field, all of them identified the lack of electricity as an important problem. Households mainly perceived the connection of the village to the national grid as the only solution to provide electric energy. The use of SHSs was hardly ever perceived as a long-term alternative of electricity supply for the overall village. In contrast, SHS experts referred to a combination of centralised and decentralised electricity supply. They suggested grid extension through the REB in areas where it constitutes an economically viable option, and the use of SHS for more remote places.

About 22% of all households throughout the three villages perceived the lack of land for agricultural purposes as a crucial problem. Due to high population density, arable land is limited throughout the country. Therefore, not all households had sufficient land to be able to earn enough income from their own agriculture, and therefore supplementary had to depend on day or seasonal labour in the agriculture or service sector. Low-income and middle-income households seemed to be the ones mainly affected by this problem, as they stated this issue significantly more often than did households with higher income. Some households remarked that the provision of agricultural loans could help them to purchase additional land for cultivation.

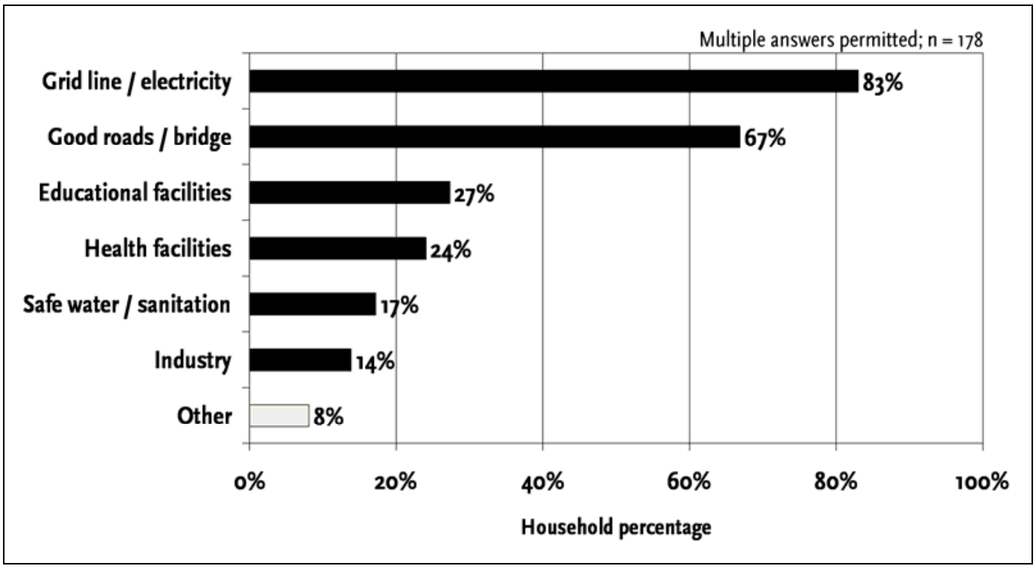
Education, water supply, sanitation, health, and proper housing were seen as important issues, but respectively stated by less than 20% of households. The insufficient availability of good educational facilities was seen as a problem across all villages and income groups. Respondents were mainly asking for the provision of more schools and madrasas through the government or NGOs. Interestingly, water supply, sanitation, and general health issues were identified as major problems mainly by high-income households. This could possibly be attributed to the higher standard of living and education of high-income households, leading to an increased awareness on health issues. Due to arsenic contamination of water resources in village C, the occurrence of answers focusing on water-related problems was three times higher compared to the two other villages. To improve the situation related to water and sanitation, households suggested the construction of more tube wells and water treatment facilities, as well as technical and financial help to build sanitation facilities such as latrines. Respondents furthermore proposed to introduce free medical treatment and the construction of health facilities to improve the overall health situation in the three villages. Insufficient housing conditions such as lack of living space, leaking roofs, etc. were problems mainly affecting low-income and middle-income households. Loans from NGOs or the government were seen as the main option to be able to improve housing conditions.

Unemployment was stated as a problem in 6% and 7% of low-income and middle-income households respectively, compared to 2% of high-income households. For some households, the construction of a factory near the village would constitute a solution for this problem.

When asked about facilities missing in the village (see Figure 14), physical infrastructure such as an electric grid line and good roads, were given highest priority by the respondents. Electricity was by far in all villages stated as being the most important missing facility. The condition of roads was especially mentioned as a problem in village A and C, where roads were unpaved and, particularly in the rainy season, constituted a major problem for local transport. Furthermore, the lack of sufficient educational as well as health facilities, safe water, sanitation and the non-existence of employment opportunities in industries were quoted.

To find out about the subjective impression of development in the village, respondents were asked whether the general living conditions in their households had increased, degraded, or stayed the same compared to the situation three years ago (see Figure 15). More than half of households perceived the developments over the last three years as positive. They mainly reasoned their impression with increased income from agriculture and business activities, as well as household members going abroad to earn additional income. The advent of electricity through SHSs was never stated as a reason for positive change. Otherwise, 16% of households stated the living conditions in their households to have degraded. Reasons for this development were quoted as a decrease in income due to loss of business and employment or health and family-related problems. Overall, 31% of households stated no change in their respective living conditions. Taking into account the answer patterns of different income groups, striking difference could be observed. Whereas 75% of high-income households stated a positive development in living conditions, only 36% of low-income households did. Degradation of overall living conditions was very low in high-income households (3%), compared to low and middle-income households (23% and 21% respectively). Obviously, the main beneficiaries of overall socio-economic development of the last three years seem to have been mainly wealthier households. This corresponds with the previous findings on income development (cp. section 5.2.2).

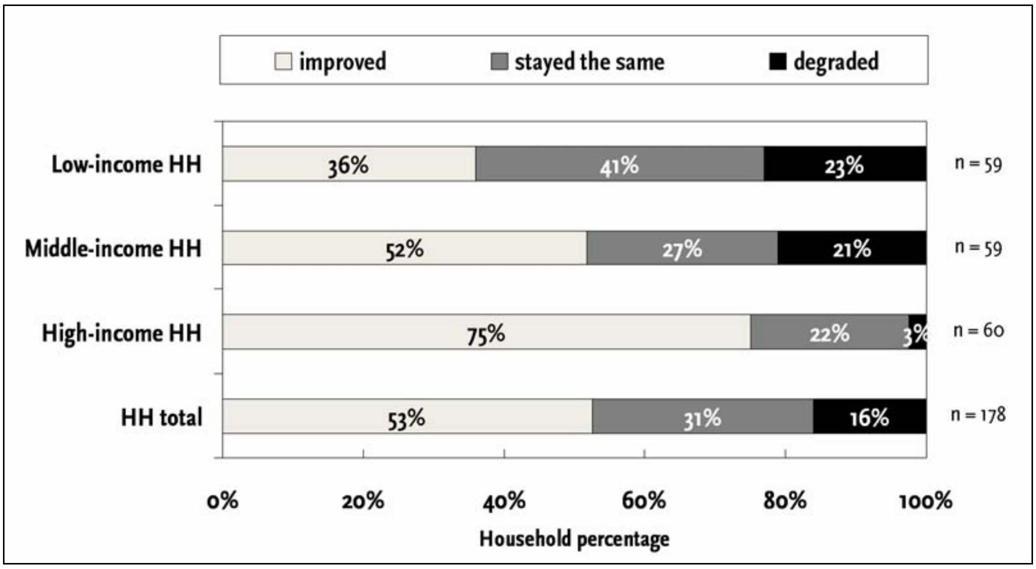
Figure 14: "Regarding village development, what is missing in your village?"



Data: Household survey, 2006; strata weighted to represent total population (see section 5.1.2)

Recapitulating, beside the lack of financial resources, electricity seems to be an important issue for rural Bangladeshi households. Its absence was perceived as a significant problem, especially by low-income households. Therefore, approaches aiming at providing local access to electricity seem to be reasonable to fulfil local households' demand. Especially households with low income did not benefit significantly from recent positive developments in income.

Figure 15: "In what way have general living conditions changed within the last three years?"



Data: Household survey, 2006; strata weighted to represent total population (see section 5.1.2)

5.3 Household energy situation

The following paragraphs will focus on the context of general energy use in the interviewed rural households, as well as their subjective impression and expectations regarding electricity. Table 4 gives an overview on the most important purposes of energy use as well as respective energy sources identified in the interviewed households, all of which will be further described in the next paragraphs.

Table 4: Purposes of energy use and main energy sources

Purpose of energy use	Main energy source	Technical application
Cooking	Biomass	Three stone stove
Lighting	Kerosene	Kupi, Hurricane lamp
	Electricity	Fluorescent tube light, LED
Entertainment, Information	Electricity	Radio, B/W TV
Communication	Electricity	Mobile Phone charger
Air ventilation	Electricity	Fan

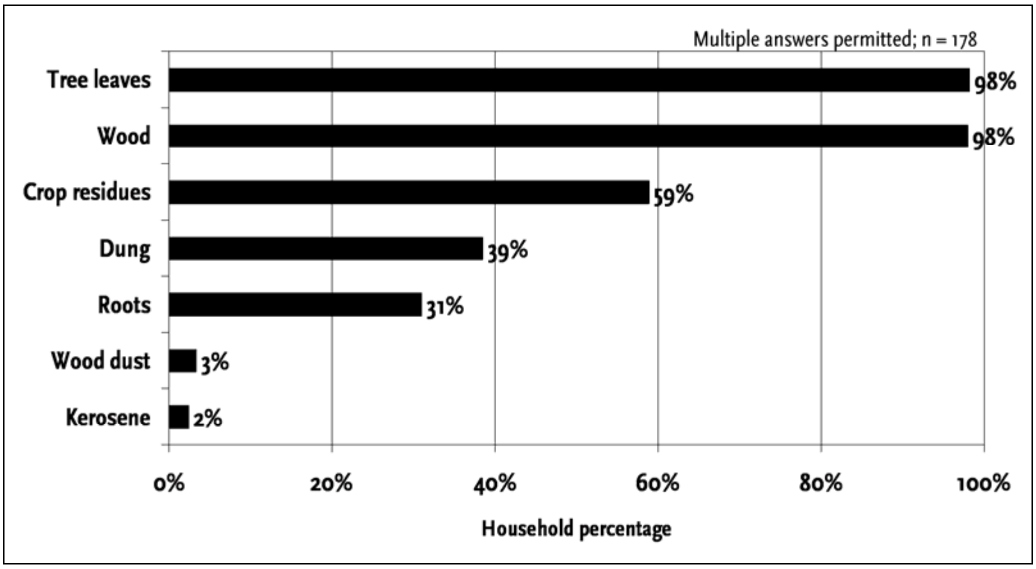
Cooking with biomass and lighting with kerosene have traditionally been the most important applications of energy in rural Bangladeshi households. This is still the case; however, due to the advent of electricity as a new source of energy, new applications for household energy use, such as entertainment and information through radio and TV, the charging of mobile phones or air ventilation (fans), have emerged. Section 5.3.1

will focus on the two 'traditional' energy sources still widely in use – biomass and kerosene - as well as respective current application and acquisition practices. The role of electricity for energy supply as well as related recently occurring energy uses will be revealed in detail in section 5.3.2. The last section of this chapter will outline the households' opinions towards electricity in general, as well as different electricity sources in particular.

5.3.1 'Traditional' energy sources: biomass and kerosene

Before the advent of electricity, biomass and kerosene had by far been the most important energy sources in rural Bangladeshi households, with biomass being the main energy source for cooking, and kerosene being the most important source of household illumination. Biomass-dominated cooking practices have remained relatively unchanged for the last decades, whereas energy patterns for lighting have recently modified slightly, with electricity becoming a growing alternative for kerosene.

Figure 16: Energy sources used for cooking



Data: Household survey, 2006; strata weighted to represent total population (see section 5.1.2)

Biomass was the main energy source for cooking in all interviewed households (see Figure 16). Only in few individual cases, kerosene was additionally used as an accelerant. For cooking purposes, the three stone stove (see Figure 17) was in use in virtually all interviewed households. It is made out of three stones or clay bricks surrounding a small fireplace. Metal pots used for cooking are placed upon the stones, directly over the fireplace. Nearly all households used wood and tree leaves for firing of stoves. In about 60% of households, crop residues such as straw were also burned. Nearly all households in village C used tops and leaves of sugar cane for stove firing, as there was ongoing sugar cane cultivation in surrounding areas as well as a sugar cane mill in a nearby village. Other common forms of biomass include dried cow dung and roots used in 39% and 31% of households respectively. In a few cases, households employed wood dust from sawmills for stove firing.

Figure 17: Three Stone Stoves, Goldapara

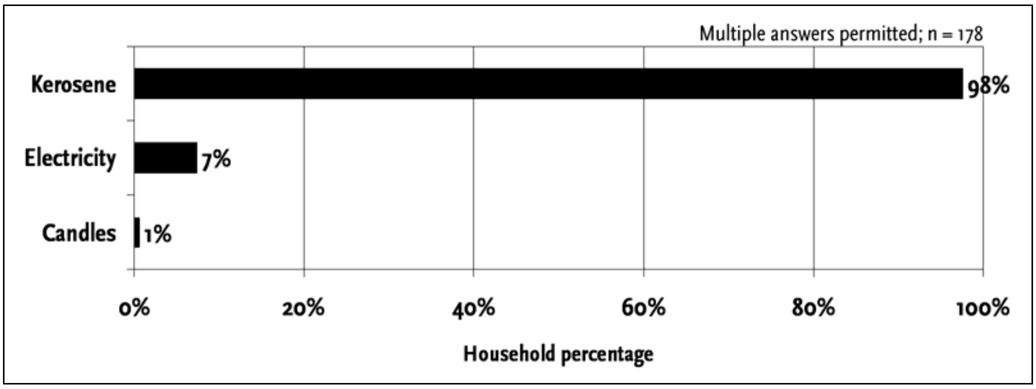
Photograph: Michael Blunck

Firewood as the most important form of biomass for cooking purposes was in 90% of cases entirely collected by household members. The remaining (predominantly high-income) households mostly collected about 50-60% of used firewood; the remaining portion was bought from the local market. Biomass collection was conducted by women in 96% of the households, followed by men (59% of households), and children (35% of households). The respective household members spent on average about 80 minutes per day on biomass collection. Households purchasing part of their firewood from the local market had average monthly expenditures of about 290 BDT, equalling about 5% of respective households' overall expenditures. However, for the whole sample, expenditures for cooking energy represented less than 1% of overall household expenditures. With wood resources becoming more and more scarce in rural Bangladesh, the price of firewood and related household expenditures increased by nearly 80% over the last three years.

As cooking behaviour was not the centre of this study, health-related impacts and problems due to cooking practices have not been investigated in detail. However, from the dominant use of biomass in combination with open three stone stoves it may be derived that indoor air pollution and related health issues might be a common problem especially for women and children in households of the study area (cp. WHO 2005). As electric stoves are virtually not in use at all in rural Bangladesh (ASADUZZAMAN 2006: 34), the introduction of SHSs could not initiate any change in cooking behaviour. Energy patterns of cooking activities have therefore largely remained the same for the last three years.

Kerosene was by far the most prevalent energy source for lighting purposes in the surveyed households (see Figure 18). Nearly all households (98%) used kerosene lamps for lighting after sunset. There were two main types of kerosene lamps in use, notably small 'Kupi' and 'Hurricane' lamps (see Figure 19). Whereas 'Kupi' lamps - consisting of a small kerosene container with attached wick - only provide very limited lighting, hurricane lamps constitute a slightly more sophisticated lighting source. It is noteworthy that even households predominantly using solar electricity for lighting, still used kerosene lamps from time to time. Especially during persistent cloudy weather or system malfunction, kerosene was still essential for household illumination.

Figure 18: Energy sources used for lighting



Data: Household survey, 2006; strata weighted to represent total population (see section 5.1.2)

Households using kerosene as the main lighting source had respective average monthly expenditures of 123 BDT, corresponding to about 3% of overall households' expenditures. These figures were significantly lower for the time three years ago, with average kerosene expenditures of 65 BDT, equalling 2% of overall household expenditures. Rising expenditures for kerosene were mainly due to the doubling of kerosene prices from an average 19 BDT per litre three years ago to 38 BDT per litre at the time of research.

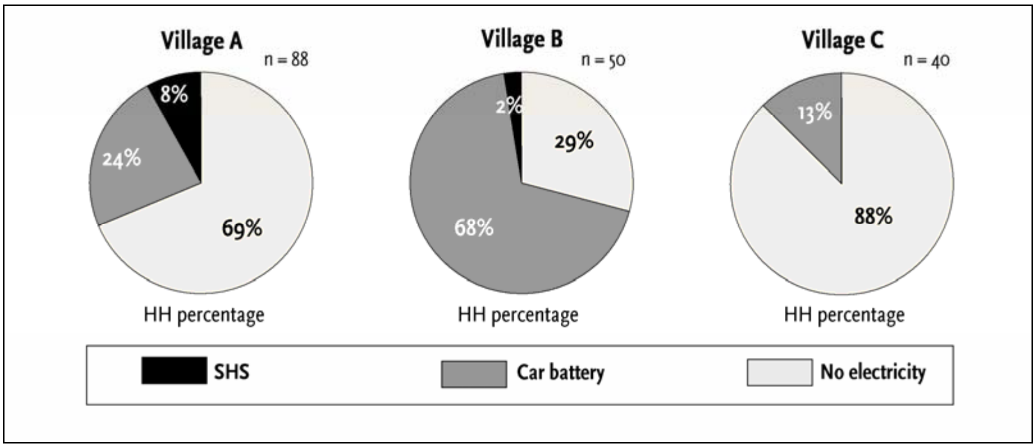
Figure 19: Popular kerosene lamps: Kupi (left) & Hurricane (right)

Photographs: Michael Blunck

5.3.2 Sources and use of electricity

All surveyed villages lacked access to the national grid line. Nevertheless, the use of decentralised electricity sources in households was quite common, with 32% of households in village A, 71% of households in village B, and 13% of households in village C receiving electricity from such sources. Overall, there were two main electricity supply options observable: conventional car batteries and SHSs. Figure 20 displays the distribution of electricity sources by village.

Figure 20: Distribution of electricity sources by village



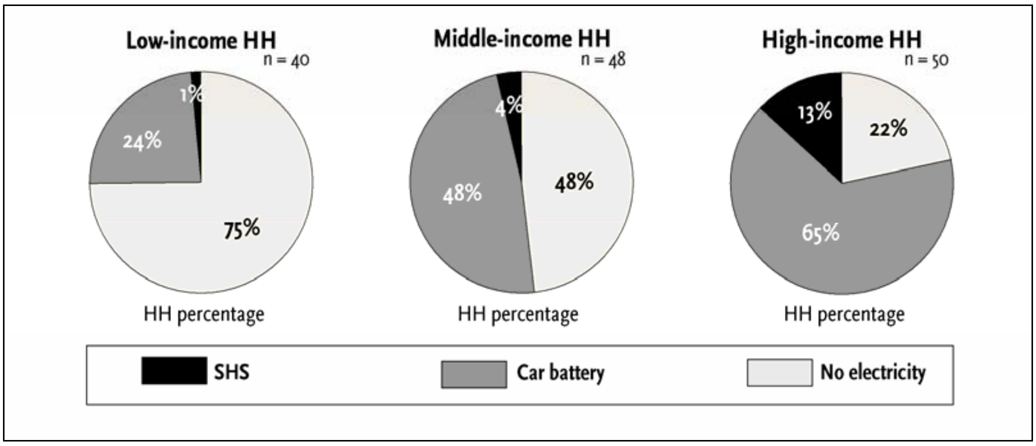
Data: Household survey, 2006; strata weighted to represent total population (see section 5.1.2)

Most households preferred the use of conventional car batteries, as they were comparatively cheap and could provide enough electricity to run a radio or black and white television. The car batteries had to be regularly charged for a fee in a nearby place with grid access. The number of households using car batteries had almost doubled during the last three years. Car batteries were particularly popular in village B, because efforts for battery charging were comparatively small with the grid line being only about 1 km away. However, even with proximate grid access, car batteries were not as prevalent in households of village C. The batteries were by average recharged every two weeks. As charging fees varied between different places, batteries were sometimes transported to villages even further away than the closest grid access point. The households covered distances of about 7 km (village A), 4 km (village B) and 1 km (village C) one-way to charge their batteries. The average overall monthly household expenditures for the use of car batteries were about 90 BDT, corresponding to 2% of households' total expenditures. Half of this amount was spent on rickshaw transport to the charging point; the other half was attributed to charging fees.

At the time of research – after three years of selling SHSs in villages A and B - the dissemination of SHSs was limited to 8% (41) of households in village A and 2.5% (10) in village B. There were no SHSs present in village C due to the non-existence of disseminating organisations. The two NGOs active in SHS dissemination in villages A and B were namely Grameen Shakti (accountable for 88% of existing SHSs) and the Centre for Mass Education in Science (CMES) (accountable for 12% of existing SHSs), with both working under the IDCOL SHS dissemination programme (see 4.2.3). Only one household purchased the SHS by paying the whole amount of money by cash, the remaining 50 households used micro financing options offered by the NGOs. Most households had signed a financing scheme lasting for 36 months. After paying an initial down payment between 2,000 and 8,000 BDT (average 4,230 BDT), these households paid monthly instalments ranging between 360 and 1,000 BDT (average 630 BDT). In a few exceptional cases, the life of the loan was only 24 months with accordingly higher monthly instalments. The amount of monthly instalments represented a remarkable financial burden, at an average equalling about 12% of SHS households' overall monthly expenditures. Even though using financing options, half of the respective households stated that they regularly had problems paying the monthly instalments, resulting in partial and belated payments.

The high monetary effort to purchase a SHS was reflected in the distribution of electricity sources by income groups in villages A and B (see Figure 21).Whereas 13% of high-income households owned a SHS, this figure was only 4% for middle-income and 1% for low-income households. This trend was also observable for the distribution of car batteries. However, overall percentages of households owning a car battery were generally higher, with about a quarter of low-income households having this source of electricity. Totalling, 75% of low-income households did not have direct access to an electricity source, compared to 48% and 22% in middle and high-income households.

Figure 21: Distribution of electricity sources by income group in villages with SHS dissemination

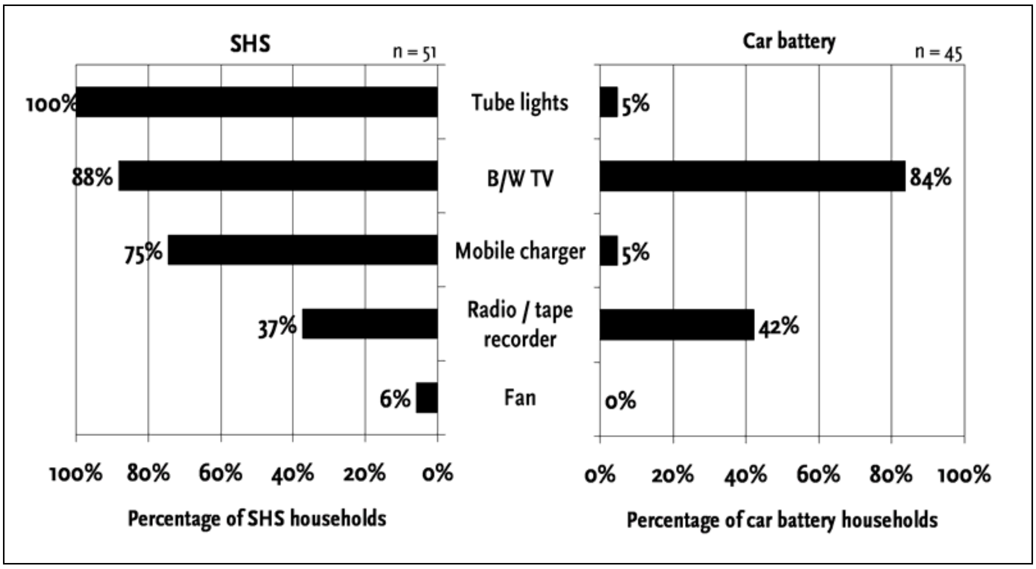


Data: Household survey, 2006; strata weighted to represent total population (see section 5.1.2)

Appliance use in households with electricity depended largely on the used electricity source, whether it being a SHS or a car battery (see Figure 22). Both being AC systems, the SHS could be purchased together with a number of purpose-built, compatible AC devices, partly manufactured by the NGOs themselves. These devices include e.g. tube lights, fans, or mobile phone chargers. As these AC devices were not readily available in the local markets, households owning car batteries were mainly restricted to the use of radios and TVs, as these were the only AC devices widely offered. All SHSs were readily equipped with a certain number of tube lights ranging between two and six per household. Being the device most frequently used by all households, their average usage time was about 210 minutes per day. To reduce their monthly expenditures three SHS households had installed one of their tube lights in the room of a neighbouring household for a monthly fee of about 150 to 200 BDT.

Most households (88%) additionally purchased a black and white TV, which was used on average for about 130 minutes per day. Mobile phone chargers (in 75% of SHS households) and radios or tape recorders (in 37% of SHS households) were other prevalent devices. Their average daily usage time was stated as 70 minutes for phone chargers and 120 minutes for radios and tape recorders. Due to the low average capacity of 50 Wp per SHS and the relative high energy consumption of small fans, these were present in only 6% of households. Figure 23 displays some typical appliances in SHS households.

Figure 22: Distribution of electric appliances for households with SHS / car battery



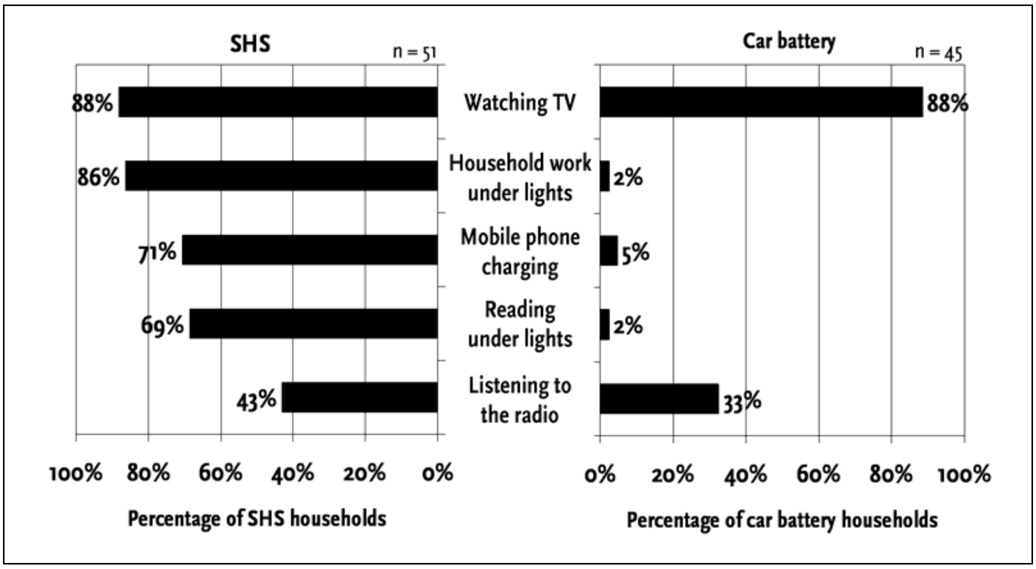
Data: Household survey, 2006; strata weighted to represent total population (see section 5.1.2)

Figure 23: Typical SHS appliances: tube light (left), TV, radio, small fan (right)

Photographs: Michael Blunck

The differences in devices use between SHSs and car battery systems was furthermore reflected in the activities performed with the help of electric energy in the respective households (see Figure 24).

Figure 24: Electricity-consuming activities in households with SHS / car battery



Data: Household survey, 2006; strata weighted to represent total population (see section 5.1.2)

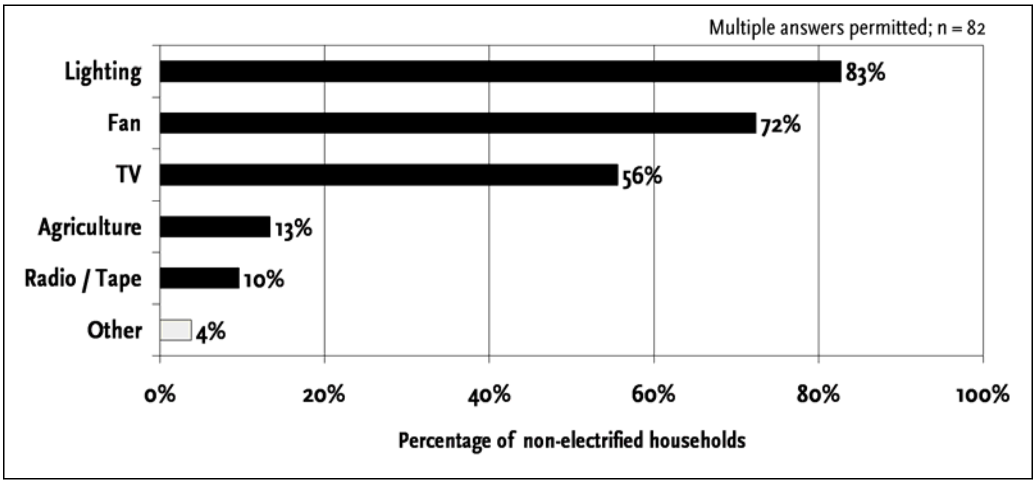
Whereas watching TV and listening to the radio were virtually the only activities facilitated by the use of car batteries, members of households owning a SHS could benefit from a broader range of electricity uses. The two most prevalent activities with electricity consumption in SHS households were TV watching and the conducting of household work under electric lights. Surprisingly for a developing country like Bangladesh, the charging of mobile phones was the third most widely performed activity, indicating an existing mobile phone network and widespread ownership of mobile phones. Reading and studying under electric lights as well as listening to the radio were two other frequently mentioned electricity-consuming activities in households owning a SHS.

5.3.3 Households' attitude towards electricity

Among non-electrified households, electricity was an omnipresent desire with 98% of respective households stating the wish to have a source of electricity in their homes. Electric lighting was the main advantage of electricity perceived by most non-electrified households. Therefore, illumination was the most frequently stated wish regarding the utilisation of electric energy (see Figure 25). Other favoured applications repeatedly mentioned in non-electrified households included the use of fans for air ventilation as well as the running of TVs. Furthermore, 13% of non-electrified households expressed the wish to use electricity for agricultural purposes such as for irrigation pumps and poultry farming[6]. Only 10% of non-electrified households were interested in using a radio. When comparing these results to the applications offered by SHSs, it becomes obvious, that only parts of the local energy demand (e.g. for lighting and TV) can be fulfilled by the use of SHSs. Due to the limited load provided by SHSs, the systems are not intended for utilisation in agriculture and can only provide very basic options for air ventilation.

Besides being mostly positive about electricity use, households without electricity sometimes noted minor reservations. Most notably, households were aware that the electricity supply from the national grid was said to be unreliable due to common power cuts and load shedding practices. Furthermore, high monthly costs as well as dangers related to electric shocks were generally stated to be negative aspects of electricity.

Figure 25: Purposes of electricity demand in non-electrified households



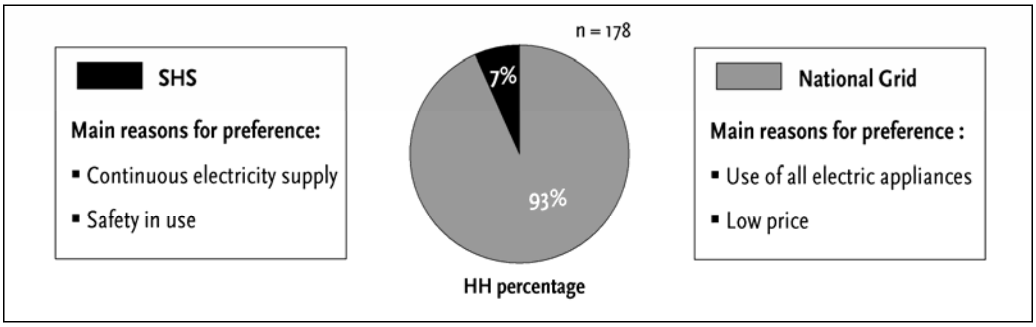
Data: Household survey, 2006; strata weighted to represent total population (see section 5.1.2)

Most non-electrified households (72%) stated to be willing to pay between 100 and 200 BDT per month on electricity. To find out about preferences regarding different sources of electricity, all households (including households with and without electric-

[6] Several poultry farmers confirmed that illumination of poultry farms increased productivity: in the evening, chicken reduced food intake and the amount of laid eggs if kept in darkness.

ity) were asked about their preferred electricity source in case of free choice (see Figure 26).

Figure 26: "If you had free choice, what would be your favourite source of electricity?"

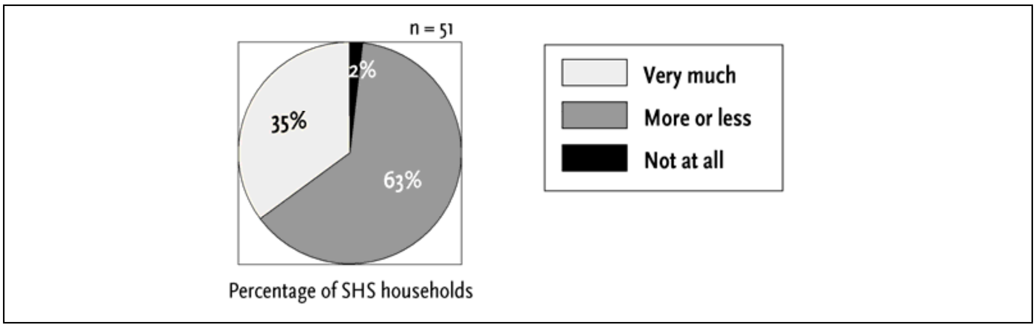


Data: Household survey, 2006; strata weighted to represent total population (see section 5.1.2)

If it were available, 93% of households would prefer electric power from the national grid, as it allows the usage of all electric devices while at the same time being relatively cheap with monthly costs of about 200 BDT. SHSs were stated to be the only reasonable alternative. However, they only were the favourite source of electricity for about 7% of all interviewed households, including only 18% of SHS-owning households. Households preferring SHSs emphasised the reliable and continuous electricity supply in contrast to grid-related problems like load shedding. Furthermore, in contrast to potential accidents (e.g. shocks) associated with grid access, SHSs were perceived a relative safe technology. Even though widely in use, the use of car batteries was revealed to be rather unpopular. Not a single households stated car batteries as their favourite source of electricity. This decision was mainly reasoned due to the limited options of device use, relative high costs, hassle concerning the carrying and charging of batteries, and the limited storage capacity of batteries in use. Not mentioned by any household, but brought up in the interviews with experts involved in SHS dissemination, was the use of diesel generators as another way of decentralised electricity generation. However, due to the high relative costs and problems regarding petrol and service availability, their application was limited to few small shops and businesses of some local markets.

SHS users were generally satisfied with their system (see Figure 27). Even though 63% of households qualified their satisfaction "more or less", all households except one stated they would willingly recommend their system to relatives, neighbours, or friends, indicating an overall contentment with the system. Just one interviewed household stated they were completely unsatisfied due to problems related to poor maintenance service from the respective NGO. When being asked about what could be improved about the existing SHSs, in nearly all cases the sole answer was to increase the system power and battery storage capacity, as households would be interested in using a wider range of appliances, such as ceiling fans, fridges, or colour TVs.

Figure 27: "How much are you satisfied with the benefits of your SHS?"

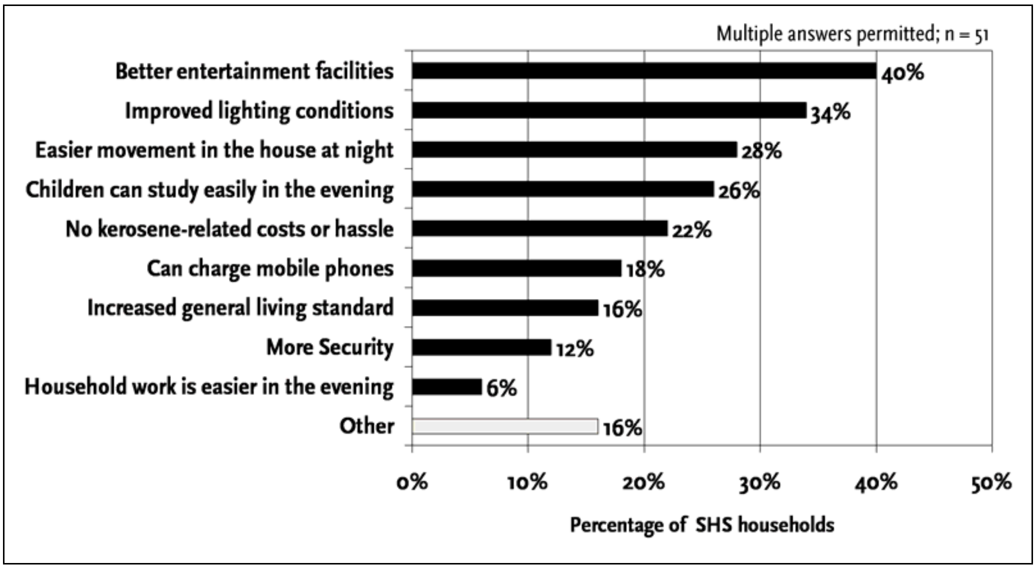


Data: Household survey, 2006

5.4 Socio-economic impacts of SHS

To reveal the subjective impression of SHS users regarding socio-economic impacts of their systems, they were asked about changes in their daily life that had occurred after system installation. Figure 28 displays the main answers that were given.

Figure 28: "What changes in daily life could be observed after installing the SHS in your household?"



Data: Household survey, 2006

Better opportunities for information and entertainment were perceived as important changes by 40% of SHS households, followed by improved lighting conditions (34%) and thus easier movement in the house at night (26%). As another benefit of lighting, the improved conditions for studying by school children were quoted in 26% of SHS households. Other frequently mentioned changes included the absence of kerosene-related hassles (e.g. filling of oil lamps, purchase of kerosene in the market, filthy air) (22%), the possibility to charge mobile phones (18%), an overall increased living standard (16%), increased security due to household lighting (12%), and facilitated household work in the evening hours (6%).

The following paragraphs will in detail focus on these benefits mentioned by affected households, as well as other impacts of SHSs that were frequently referred to during the interviews with SHS experts.

5.4.1 Income and productive use of electricity

An increase in income generating activities and a therewith-connected rise of income is in many cases one of the major arguments for rural electrification programmes. For the case of SHSs in households, however, many former studies have concluded that there is little or no evidence of direct economic impacts (VAN CAMPEN et al. 2000: 17). Still, VAN CAMPEN et al. (2000: 17) noted that there are individual studies stating potential income-generating activities emerging due to the introduction of SHSs; overall, however, there seems to be a lack of research devoted to analysing the home economics sector. For the case of rural businesses, most existent studies present a unanimous picture. Prolonged working hours due to lighting, attraction of more customers, and an improved quality of the productive activity are frequent findings of previous SHS studies (VAN CAMPEN et al. 2000: 32). Most of the experts involved in the Bangladeshi SHS dissemination process clearly emphasised the potential of SHSs for income-generating activities such as nighttime illumination of cottage industries (e.g. sewing, handicraft production) or small-scale agricultural applications (e.g. illumination of poultry farms). Furthermore, the use of SHSs in small businesses and shops and therewith-connected longer opening hours and increased income were frequently mentioned. Production-related information was therefore collected in both households and a small sample of shops and businesses of a local market to reveal information about the actual situation of income-generating activities facilitated by the use of electricity.

Irrespective of electricity utilisation, the number of overall income-generating activities performed in or nearby the interviewed households was quite low, as most income-generating activities were performed outside the household premises, e.g. in the fields, in workshops, on a rickshaw, etc. In just 12 (8%) households - all belonging to the group of high-income households - productive activities such as sewing (4 households), poultry farming (4 households), milk production (3 households) or husking of rice (1 household) were observable, with an average additional income of about 1,500 BDT due to the respective activity. As most activities were conducted during daytime and the provided solar electricity load was too small for the use of productive appliances or machinery, only two households were using electricity for income-generation, notably illumination of one poultry farm by the use of a car battery, and sewing under electric lights in one SHS household. The SHS household accounted an increase in income of about 100% due to longer sewing hours in the evening. As this was the only case of its kind, general assumptions regarding income-related benefits from SHS use cannot be drawn. Even though predicted by most SHS experts, income-generating activities due to electricity use were not yet very prevalent. The author's observation was in many cases that, as most SHS households already had relative high incomes, they preferred using their additional evening time for entertainment activities instead of income-generation (cp. section 5.4.3). Low-income households that probably would have gained the biggest relative income benefits from longer working hours were at the same time the ones that could not afford the purchase of a SHS. Most SHS experts also shared this impression.

Across the board, all nine interviewed shops reported an increase in income during the last three years, irrespective of SHS ownership. However, all businesses using a SHS confirmed improved customer appeal and therewith-higher income due to the availability of electricity. They stated four main reasons for this development:

- Attraction of a new clientele
  Electric lighting provided improved illumination of the goods and services for sale, attracting more customers to the electrified shops in the evening. Furthermore, the

availability of TVs (see Figure 29) was another factor, pulling new customers to electrified shops.

- Higher income from regular customers
  As many households do not own a television set, a lot of people gather in front of electrified shops at night to watch TV. Thus, customers tend to stay longer in shops with TV, spending more money on drinks and snacks.

- Diversification of offered services
  Solar electricity enabled one shopkeeper to offer new electricity-based communication services, such as telephone facilities and mobile phone charging. It was stated, that these services provided a good additional income.

- Longer working hours
  One tailor shop with SHS (see Figure 29) emphasised the advantage of being able to work for longer hours in the evening. The electric lights provided the necessary high quality lighting for the tailoring work at night. As the local bazaars were most active during the evening, the tailoring shop was now able to open during that time and therewith enlarge his clientele.

Figure 29: SHS use in businesses: grocery with TV (left), tailor shop with electric lights (right)

Photographs: Michael Blunck

All shops and businesses stated SHS ownership to be an important factor for local competition. However, this at the same time revealed a potential critical issue. The three shops who could not afford the usage of a SHS all reported reduced numbers of customers. This development was accounted to old customers being more attracted by the brightly illuminated SHS shops offering facilities such as TV or telephone. Therefore, SHSs could be a factor tightening the local competition leading to a decline in business for shopkeepers who cannot afford to purchase a SHS, while increasing the income of affluent shopkeepers having the financial resources to invest in solar electricity. Due to the small sample of interviewed businesses, however, it cannot be stated that this trend, observed throughout the nine interviews, is implicitly valid for all cases. The author strongly advices that this development be kept track of and further research focusing in detail on the impacts of SHSs in local markets be conducted.

5.4.2 Energy expenditures

As specified in chapter 3, previous studies identified potential monetary savings due to the switch from traditional household fuels to grid electricity. Van CAMPEN et al. (2000: 18) referred to this aspect as a "rudimentary" indicator, which was used only in few SHS impact studies. However, in certain country cases, actual savings could amount up to US$ 10 per month. As most SHS experts emphasised its importance as an economic benefit for Bangladeshi households, this study collected some related field data.

For the study area in Bangladesh, lighting was the only energy application with a fuel switch observable in SHS households, with electric lighting replacing on average 80% of kerosene consumption. The following analysis confines itself to SHS households using 36 months credit schemes, as these were most prevalent. To determine short-term household savings within the credit repayment period, the average monthly lighting expenditures for SHS households and non-SHS households in villages with SHS dissemination are brought together in Table 5. Kerosene expenditures did not totally vanish for SHS households as most of them still used small amounts of kerosene for additional lighting or in the case of cloudy weather.

Table 5: Average monthly lighting expenditures in SHS and non-SHS households within the first 36 months of SHS ownership (in BDT/month)

	Non-SHS HH	SHS HH
Kerosene purchase	121	24
SHS – instalments	-	630
Total	**121**	**654**

Data: Household survey, 2006

It is apparent that within the credit repayment period of 36 months, monthly expenditures for lighting in households with SHS were more than five times as high as in households purely relying on kerosene. When taking into account the average initial down payment of 4,230 BDT for acquiring a system, the first three years of SHS ownership are characterised by striking accumulative expenditures for lighting in SHS households (see Table 6). Within this period, expenditures for lighting in SHS households exceed those in non-SHS households by more than factor six.

Table 6: Average accumulative lighting expenditures in SHS and non-SHS households within the first 36 months of SHS ownership (in BDT)

	Non-SHS HH	SHS HH
Kerosene purchase	4,356	864
SHS – down payment	-	4,230
SHS – instalments	-	22,680
Total	**4,356**	**27,774**

Data: Household survey, 2006

As after the repayment period expenditures for lighting in SHS households were limited to costs resulting from small expenses for supplementary kerosene (on average 24 BDT/month) as well as the five-yearly replacement of the battery (6000 BDT/5 years) the higher expenses of the repayment period could possibly be slowly amortised. Information from experts involved in the SHS dissemination process, revealed a respective timeframe of about 15 to 20 years.

However, taking into account average values for all mentioned cost factors[7], the average extra costs for a SHS would not amortise within the operating time of the system, which is approximately 20 years. The overall expenditures for 20 years of household illumination would be on average 51,000 BDT for SHS users and 29,000 BDT for households solely relying on kerosene, implying lighting expenditures in SHS households being 76% higher compared to non-SHS households (see Table 7).

However, in certain households, the utilisation of the cheapest available SHS option in combination with high previous kerosene expenditures can actually result in small savings or at least covering of the extra expenses for the SHS. The utilisation of

[7] See Table 5; Down payment for SHS: 4,230 BDT; Cost of 5-yearly replacement of the battery: 6,000 BDT

the cheapest available SHS option (down payment: 2,000 BDT, instalments: 360 BDT/month) assumed, amortisation of additional expenditures within 20 years would arise for households currently having kerosene expenditures of more than 160 BDT. This would apply for 18% of non-SHS households in villages with active SHS dissemination. However, the only system of this price range installed in village B was used for lighting purposes only as the provided load was too low to run a TV. Nevertheless, as kerosene prices are on the rise, almost doubling during the last three years, SHSs that are even more sophisticated might become financially attractive to households previously having high monthly kerosene expenditures in the future.

Table 7: Average accumulative lighting expenditures in SHS and non-SHS households after 20 years of SHS operation (in BDT)

	Non-SHS HH	SHS HH
Kerosene purchase	29,040	5,760
SHS – down payment	-	4,230
SHS – battery replacement	-	18,000
SHS – instalments	-	22,680
Total	**29,040**	**50,670**

Data: Household survey, 2006

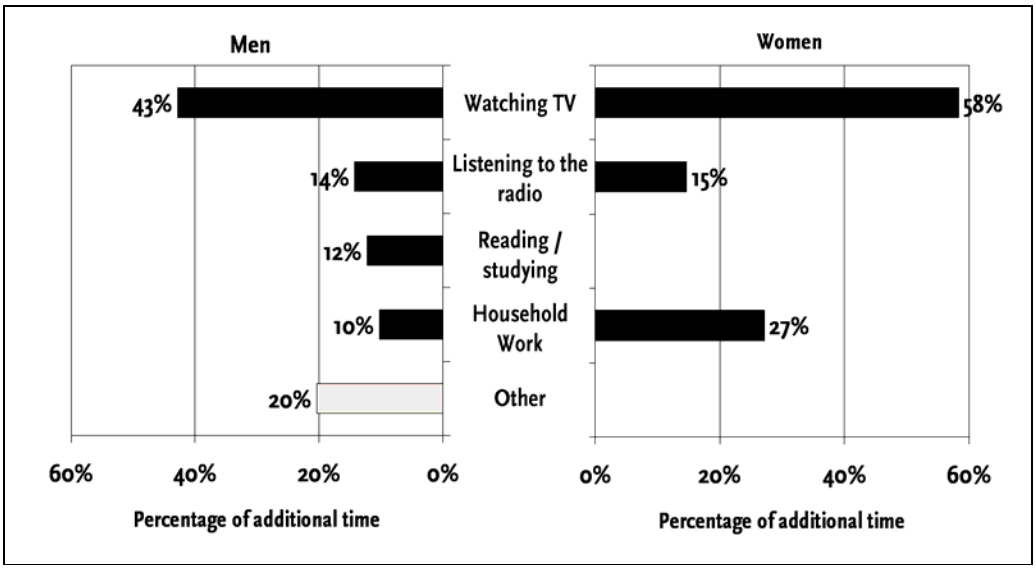
Recapitulating, it can be stated that at the time of research, in most cases overall expenditures for the SHS did not amortise due to reduced kerosene expenses. However, in the case of low-cost SHSs used in households with previous high kerosene consumption, SHSs might represent a financially attractive alternative to illumination with kerosene in the long term. Still, the high initial costs during the repayment period of the loan will likely not be affordable to most low and medium-income households. Therefore, beneficiaries of monetary savings from SHSs will mostly be limited to more affluent households.

5.4.3 Time use and length of day

As mentioned in chapter 3, most impact studies on rural grid-based electrification programmes revealed an overall prolonged day and therewith connected surplus time in electrified households due to the availability of electric lighting. Van Campen et al. (2000: 18) stated the additional time gained daily from the use of SHSs as an easily quantifiable impact indicator that could be linked with a potential impact in income generating activities. They mention several studies on SHSs, identifying an average surplus time of between 1.5 and 2 hours per day for households in different country cases (VAN CAMPEN et al 2000: 17-18). Interviewed Bangladeshi SHS experts in many cases stated that members of SHS households went to bed much later in the evening, therewith gaining more time for activities such as reading, production, or recreation.

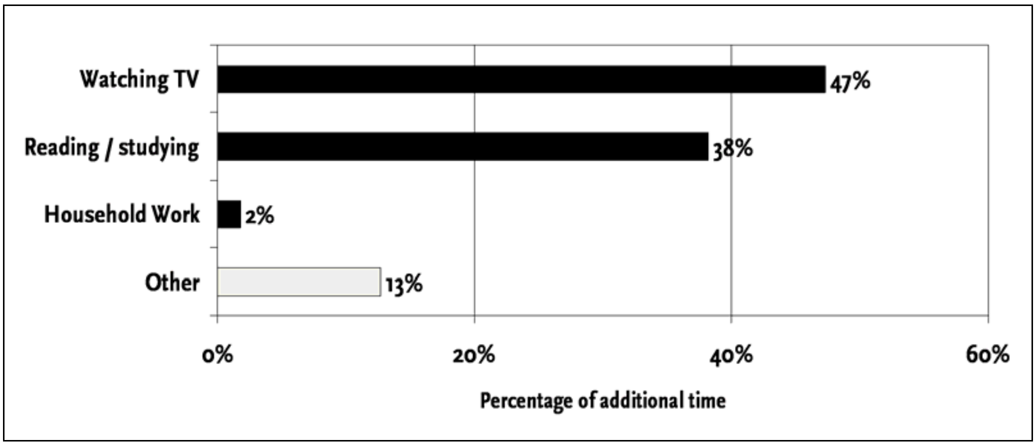
To gather data on the length of day in different Bangladeshi households, household members were asked to provide information on activities performed after sunset as well as respective expenditures of time. Data for respective households with and without SHS in the two villages with SHS dissemination were compared afterwards. In comparison to non-SHS households, members of SHS households extended their evening hours on average by 40 minutes. Figure 30 displays a breakdown of different activities performed by adults during this surplus time. In contrast to assumptions regarding productive activities performed in the evening hours, actually about half of this time was used for watching TV. 15% of adults' time was furthermore used for listening to the radio. While male household members used the remaining third of time for reading and other activities mainly conducted outside the household premises, such as visiting friends and business activities (not connected to SHS use), women predominantly stayed at home and used the remaining time for household-related work. Besides watching TV, children used 38% of their additional time for reading and studying (see Figure 31). Other activities such as playing represented the remaining 13% of children's extra time consumption.

Figure 30: Adults' use of extended evening hours in SHS households



Data: Household survey, 2006; strata weighted to represent total population (see section 5.1.2)

Figure 31: Children's use of extended evening hours in SHS households



Data: Household survey, 2006; strata weighted to represent total population (see section 5.1.2)

Analysis of evening activities in the surveyed households revealed prolonged evenings and therewith overall additional time available for activities of all household members. However, for the Bangladesh case, in sharp contrast to assumptions by VAN CAMPEN et al. (2000: 18), this fact should not be referred to as an indicator for potential income generating activities. Instead, watching TV was identified as the dominant evening activity for all household members, besides household work (women) and reading/studying (children). However, even if generally not called productive, activities like household work and studying are of course not less valuable. They will be in focus of the next two paragraphs.

5.4.4 Household workload

A decrease in the time necessary for conducting women's household work due to the use of electric household appliances (e.g. blenders, washing machines) was frequently identified by previous studies on impacts of grid electrification. For the case of SHSs, reports on reduced workload have been rare to this point in time. Studies stating such developments have as yet been mostly isolated cases, such as the use of electric blowers for cook stoves in China. Some researchers on energy and gender issues, however, highlight the potential impact in areas such as the time savings in water collection by energising water pumping, and the use of small appliances such as blenders on which future project design should put emphasis (VAN CAMPEN et al. 2000: 21). The main problem in most cases remains the low amount of energy provided by the SHS and therewith-limited options for household application. This is also the case in Bangladesh, where, except from electric lighting, none of the interviewed households reported ownership of appliances facilitating household work. Moreover, none of the SHS experts referred to impacts on households' workload due to SHS use.

A quantitative analysis revealed no decrease in daily working hours for men or women during the last three years. Irrespectively from SHS ownership, the respective working time had rather increased from 7.9 to 8.7 hours per day for women and from 8.8 to 9.4 hours per day for men. This development can possibly be related to the overall increase in economic activity observable for the study area. A potential influence of SHSs can be ruled out, as no significant changes in the situation of SHS and non-SHS households were observed.

Apart from quantitative changes in daily working hours, household members were asked about their subjective impression regarding their daily workload. Thereby, gender-specific differences were observable. Focusing on SHS usage, 29% of respondents stated that male household members benefited from reduced workload, while this figure was 41% for female household members. Men were stated to benefit mainly from the avoidance of going to the market to purchase kerosene. Women emphasised the convenience of finishing household work at night with improved lighting conditions. Furthermore, the avoidance of filthy kerosene-related work, such as the filling of kerosene lamps, was frequently mentioned as an aspect improving the daily working conditions of female household members.

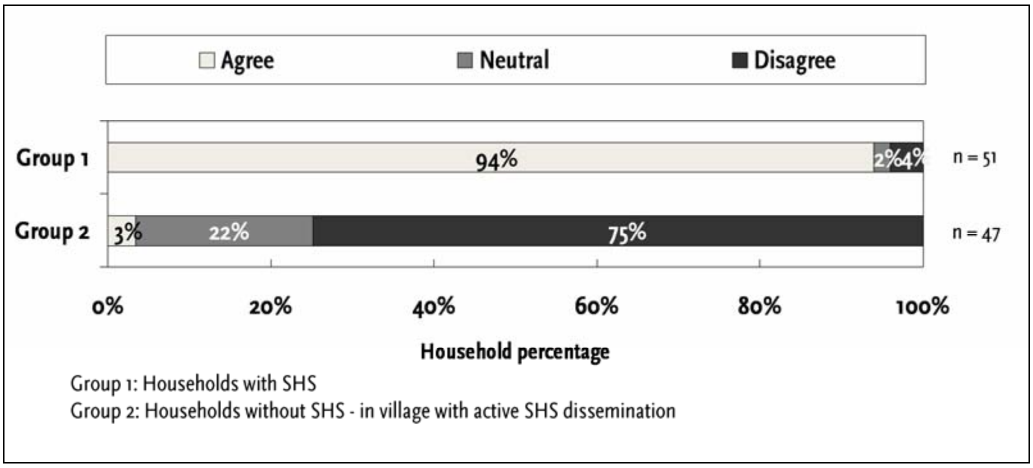
Overall, it can be summarised that the quantitative workload in the surveyed households was not reduced due to the use of SHSs, the main reason being the absence of low-voltage household appliances. However, qualitative conditions for household work seem to have improved especially for female household members due to improved illumination of household activities (e.g. cooking, cleaning) and the avoidance of kerosene-related inconvenience.

5.4.5 Education

Rural electrification is in general often associated with improved conditions for education due to electric lighting in households, as well as lighting and electric equipment in rural schools. In line with findings for grid electrification, VAN CAMPEN et al. (2000: 20) cited in existing SHS studies a consensus on improved conditions for education due to improved lighting conditions in rural SHS households. Due to the use of audio-visual teaching aids, the quality of rural educational facilities may improve. Furthermore, schools could extend their time of teaching into the evening hours. All Bangladeshi SHS experts pointed out the possibility for school children to study under electric lights in the evening to be a very important issue. Their impressions on benefits for rural schools were rather mixed. Overall, the diffusion of SHSs in rural schools still seemed to be quite low; a result of very limited needs for electricity. As most classes were predominantly running at daytime, lighting as such was not an urgent necessity. Furthermore, as there were no community-based approaches for school electrification existent in most SHS dissemination programmes, there was yet no viable option for the large-scale financing of SHSs for schools in sight. However, individual systems already installed in rural schools showed some potential benefits. SHSs were described as having the potential for lighting on cloudy days during the monsoon as well as providing the possibility of holding evening classes e.g. for adult education. Furthermore, children enjoyed the convenience of fans during the hot summer months.

Improved conditions for children's studying were mentioned by many households to be an important benefit (cp. Figure 28). Figure 32 shows a significant higher agreement with the statement "In my house it is easy to read in the evening" for SHS households compared to non-SHS households in the same respective villages, indicating superior quality of reading and studying activities.

Figure 32: "In my house it is easy to read in the evening" – Overall agreement



Data: Household survey, 2006

The overall time spent on studying per evening was on average 21 minutes longer in SHS-households (133 minutes) in contrast to households without solar electricity (112 minutes) in the same village. Interviewees confirmed that improved lighting conditions seemed to motivate rural school children to spend more time studying, whereas children working under the light of kerosene lamps were not tempted to exceed education-related activities. This seems to be understandable as reading with the aid of kerosene lamps was described to be very straining on the eyes.

Even though the impacts from electrified educational institutions remain very low due to their low prevalence, the educational situation of rural households seems to have improved with the advent of solar electricity. Especially the children in SHS households benefited from improved electric lighting for their studying, causing longer overall studying hours of more than 20% for children in solar-electrified houses compared to children from other households in the same village.

5.4.6 Health

As for the educational impacts, health-related issues have to be considered from the household point of view as well as from the perspective of rural health institutions. On household level, improved indoor air quality and increased awareness regarding health issues were important impacts previously related to rural electricity supply in general. Furthermore, improved conditions for rural health centres due to electricity supply were often said to have an impact on the overall health situation. With respect to SHS use, many studies identified refrigeration possibilities, absence of smoke from traditional lighting sources and a reduced risk of fire as positive aspects (VAN CAMPEN et al. 2000: 20). Vaccine refrigeration, better emergency care at night, as well as radio communication were often mentioned benefits of solar system use in rural health facilities, such as clinics or health stations. Infrequent, but also in use are nebulisers, centrifuges, sterilisation, and water treatment equipment (VAN CAMPEN 2000: 24). For the Bangladeshi case, SHS experts did not refer to direct health impacts on household level. Significant benefits for rural health institutions, however, were often noted. As for the case of rural schools, SHSs are not yet widely prevalent in rural health institutions. Nevertheless, where existent, they are mainly used for lighting purposes enabling improved treatment of patients at night. In most conversations with SHS experts, the high potential of vaccine refrigerators for the improvement of rural health services was emphasised. Still, these systems were not widely available and therefore hardly in use.

Some interviewed respondents on household level pointed out that the indoor air of their homes felt fresher to them, as smoke and emissions from kerosene lamps were now avoided. Whether the absence of kerosene emissions will lead to a long-term improved health situation due to a decrease in incidence of respiratory or eye diseases could not be evaluated. For the moment, after the three years of SHS dissemination in the surveyed villages, no difference in the occurrence of respective diseases between SHS and non-SHS households could be observed.

Many households stated to regularly follow programmes on radio and TV related to health issues therewith increasing their knowledge base on topics such as prevalent diseases or hygiene. In the long-term, increased awareness could result in an overall improved health situation. For more information regarding TV and radio use please refer to section 5.4.7.

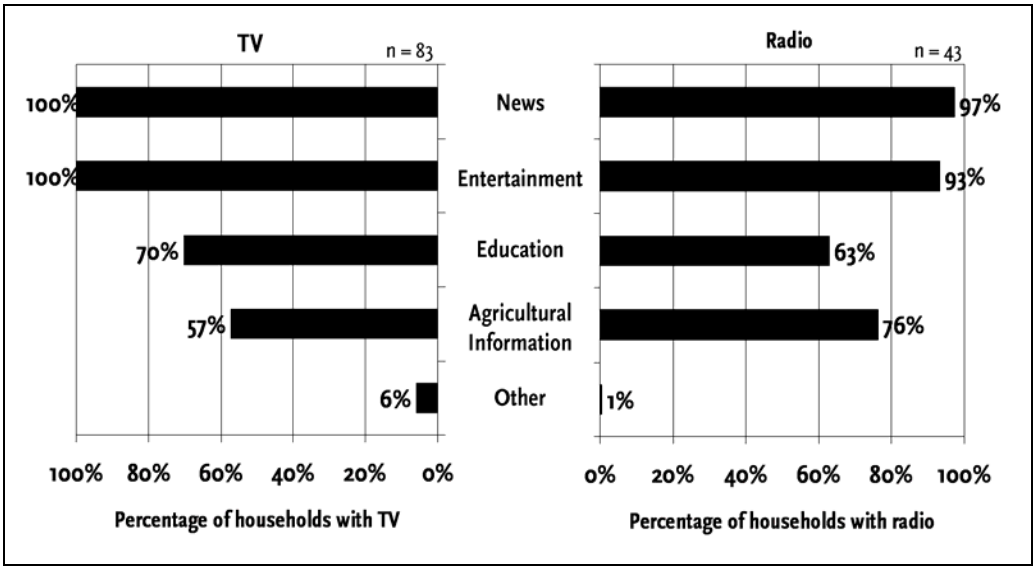
Even though generally not very prevalent, the risk of accidents from kerosene use (e.g. burns, fires) was considerably reduced due to the sparse usage of kerosene in SHS households.

Solar-electrified health institutions were not yet very prevalent. The potential of solar technology for the improvement of respective facilities, however, seems to be high, especially with regard to vaccine refrigeration. Even though not resulting in an immediate improved health situation, improved indoor air, and increased awareness on health issues as well as reduced accidents due to kerosene use are factors probably contributing to overall improved health in SHS-households on a long-term basis.

5.4.7 Information and entertainment

The use of TV and radio is one of the most apparent applications identified in all previous impact-related studies on electricity use. As it is technically feasible, even with loads as low as 50 Wp, the use of black and white television sets is very common in SHS households worldwide. VAN CAMPEN et al. (2000: 18-20), summarising the impacts of studies on solar-powered TVs and radios, state potential positive as well as negative effects of the increased use of audiovisuals. Economically, access to information on the weather forecast was stated to be a significant benefit for populations highly dependent on weather conditions, such as herdsmen. Furthermore, TV and radio could deliver market reports and therewith provide rural people with access to information on market prices. Generally, the availability of national and international news as well as entertainment programmes are seen as important factors improving the overall quality of life of rural households. The benefits of TV for adult education and training programmes are also pointed out. The negative impacts of TV and radio, however, such as creating disenchantment with rural life especially among the young and the deterioration of traditional cultural values was also reported. Bangladeshi SHS experts especially emphasised the considerable social impact of TV use. They pointed out the increased social awareness as well as knowledge about national and international events among SHS users. Increased knowledge on health topics as well as agricultural techniques from respective TV programmes was also frequently mentioned. Ultimately, the high relevance of improved entertainment facilities for rural households was noted.

Figure 33: Regularly watched TV and radio programmes



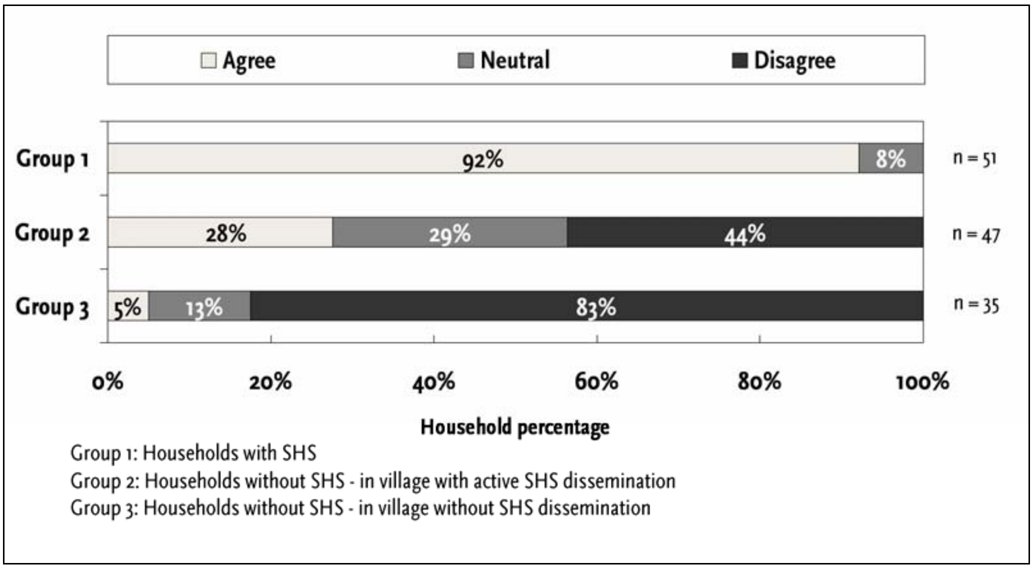
Data: Household survey, 2006; strata weighted to represent total population (see section 5.1.2)

Through the household survey, all of these potential benefits mentioned by SHS experts could be verified for most cases. The overall prevalence of audiovisuals in SHS households was high for TVs (88% of SHS households) but slightly lower for radios (37% of SHS households). Figure 33 displays the types of TV and radio programmes regularly followed by household members. Virtually all households watched entertainment and news programmes on a regular basis. More than every second household with radio or TV regularly watched educational as well as agricultural programmes.

Respondents especially highlighted the amenity of the newly available entertainment options through broadcasting of local movies and TV series. Whereas before the advent of electricity people after a long working day went to bed early, TV and radio now offered better options for "mental recreation".

Most households explained that due to radio and TV, they were now able to receive information about what was going on in their country as well as in the world, making them more aware of political and social issues. The availability of national and international news was perceived to be quite important, as beside TV and radio, other sources of information were scarce or not accessible (e.g. due to high illiteracy). Figure 34 shows that the subjective perception of information access differed significantly between households with and without SHS. As non-electrified households frequently visited their TV-owning neighbours, the availability of SHSs in the neighbourhood of the same village seemed to improve the information flow even for neighbouring households without an own SHS (see 5.4.11 for details on indirect impacts of SHSs).

Figure 34: "It is easy for my family to get news and information" - Overall agreement



Data: Household survey, 2006

The following of educational programmes was notably prevalent in 70% of households owning a TV and 63% of households owning a radio. Programmes included a popular alphabetisation programme watched by children as well as adults alike and health-related information programmes, which were pointed out to be a useful source of knowledge. Agricultural programmes were also available on local TV channels. A regularly broadcasted programme provided information on agricultural techniques, and was perceived to be very useful for the respective households' agricultural activities. Many respondents noted the radio weather forecast to be very helpful for the planning of agricultural activities.

Besides the benefits resulting from TV and radio, 18% of SHS households noted negative impacts. Children were sometimes distracted from studying, as they preferred watching TV in the evening. However, as overall studying hours in SHS households were still significantly higher compared to non-SHS households, this can be interpreted as a minor negative impact. In a few cases, frequent visits from neighbouring families for TV watching were perceived to be annoying.

Recapitulating, access to consumer electronics such as TVs and radios had considerable impacts on rural Bangladeshi households owning a SHS. In the households' subjective perception, entertainment facilities were a prominent benefit, providing a bigger variety of options for "mental recreation". Regarding development-related impacts, the improved flow of information in SHS households but as well in neighbouring non-SHS households was a very important factor. News and information provided increased awareness on current social and political issues, as well as on health topics. Furthermore, alphabetisation programmes were popular among the interviewed SHS households. In a long-term perspective, this might increase literacy for children as well as adults. With the help of agricultural programmes, information on agricultural techniques and innovations is efficiently distributed.

5.4.8 Telecommunications

Even though not the focus of many electrification impact studies, electricity is a key precondition for the emergence of telecommunication technologies. VAN CAMPEN et al. (2000: 33-34) emphasises the importance of solar PV for the provision of rural telephone services, for example in the form of PV-powered mobile phone communication centres, offering telecommunication facilities for rural communities. As landline telephone connections are rare in rural areas of Bangladesh, conversations with SHS experts revealed an especially high potential for the use of SHSs for mobile telecommunication purposes.

Overall, there are already about 14 million mobile phone users in Bangladesh. The country's biggest mobile phone network, Grameen Phone, has more than 10 million customers alone, covering a remarkable portion of the country, even in relatively remote areas with low electricity coverage (Grameen Phone 2006). Besides the provision of telecommunication services through small businesses (cp. section 5.4.1), SHSs enable private households to recharge their own mobile phones. In fact, 75% of all SHS households possessed a phone charger, indicating the broad dissemination of mobile phones in the rural areas. Households enjoyed the advantage of being able to charge the phones in their homes instead of having to cover long distances to the next village with grid electricity. As power consumption of the chargers was low, members of neighbouring non-electrified households were usually allowed to use the chargers present in SHS households free of cost.

SHSs had significant influence on the use of mobile phones in remote rural areas, mainly due to the possibility of charging the phones. Improved options for telecommunication may constitute a potential beneficial factor for future business development and growth.

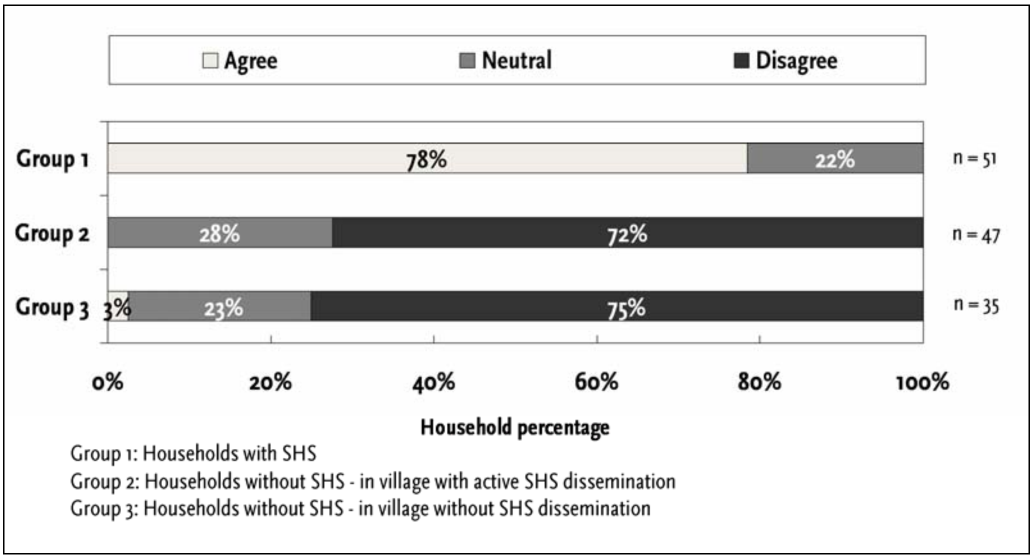
5.4.9 Perceptions of safety and social activity

Previous research rarely studied the impact of electricity on a community's social activity. However, some studies highlighted the importance of electric lighting – in households as well as for public lighting - for an increased feeling of security. As some interviews with Bangladeshi experts confirmed, the potential impacts on safety perception and social activity in villages with SHSs may not be insignificant. As at least one lamp of the SHS was often installed outside near the entrance of houses, even some outer parts of the household premises were illuminated. This provided more security at night especially for women, who thus went out more often. Furthermore, theft especially from poultry and chicken farms could be avoided through the use of SHS illumination. As even mosques, temples and public rooms sometimes used SHSs for lighting purposes, therewith connected social activity could be promoted.

The household survey did not cover the influence of SHSs on security and social activity in depth, however, respondents were asked to state their amount of agreement regarding the two statements "I feel safe in my household in the evening" and "We often socialise with friends, relatives, or neighbours at our home in the evening". The results are displayed in Figure 35 and Figure 36 respectively.

Members of SHS households appeared to have a much higher feeling of security compared to non-SHS households. Respondents often stated they felt that the risk of theft was significantly reduced due to the availability of electric lighting in their houses. However, as can be seen in Figure 35, the feeling of security of non-electrified households in villages with SHSs does not significantly differ from households in non-electrified villages. As SHSs were not yet that widely disseminated and no public lighting system was in place, the overall lighting conditions in all villages irrespective from SHS availability remained poor.

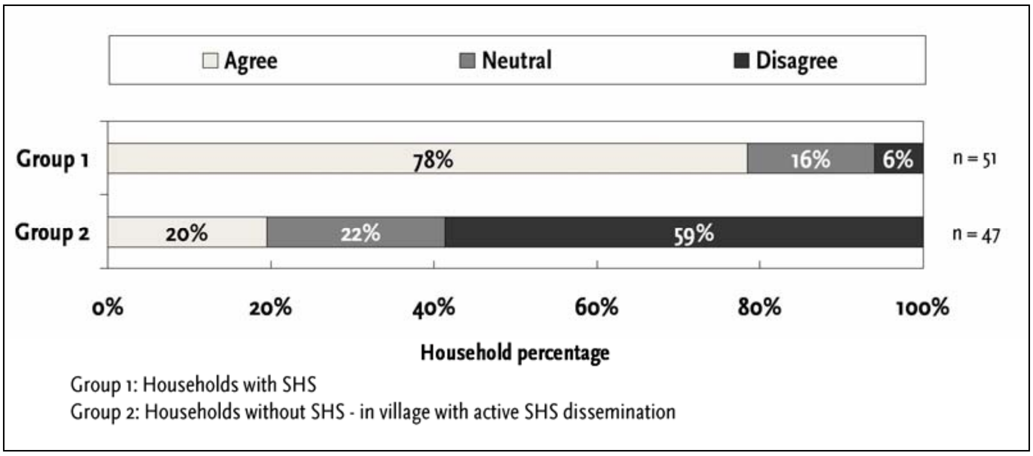
Figure 35: "I feel safe in my household in the evening" – Overall agreement



Data: Household survey, 2006

After sunset, the occurrence of social gatherings seemed to be highly influenced by the availability of electric lights and television sets. Figure 36 reveals that most SHS households stated to frequently host social gatherings in the evening, as neighbours were attracted by good lighting and TV facilities. In contrast, households not having solar electricity were more seldom receiving visitors in the evening hours. It should be remarked, however, that in households with car batteries, even more social activity was observable in the evening than in those households without any electricity source. This was mainly due to the availability of TV facilities.

Figure 36: "We often socialise with friends, relatives, or neighbours at our home in the evening" - Overall agreement



Data: Household survey, 2006

Both perception of safety and social activity seemed to be positively influenced by the availability of electricity. Impacts on security, however, were limited to the respective SHS households, not affecting neighbours without electricity. The increase of social gatherings in households with SHS was not found to be an effect of increased mobility due to better safety conditions, but could be exclusively ascribed to the availability of electric lighting and TV, attracting neighbours to visit SHS households more frequently.

5.4.10 Migration

Previous findings differ about electricity's potential influence on migration patterns. Whereas advocates of rural electrification claim its impacts on rural economy and living conditions reduce migration tendencies, other studies remarked that it was due to an overall raise in income and living standards that migration from rural to urban areas becomes more attractive, as needed facilities for higher education and high-income jobs are mainly available in the urban areas. For the case of SHSs, statements on impacts regarding migration have been rare, however in some cases respondents of surveys noted that SHSs could help to slow down rural-urban migration (VAN CAMPEN et al. 2000: 20). Experts involved in the SHS dissemination process in Bangladesh pointed out that there were multiple causes for rural-urban migration. As electricity was only one factor of many influencing overall rural living conditions, instant impacts on migration figures after the installation of SHSs were very unlikely. However, in combination with other development interventions, e.g. in sectors such as economy, education, water supply, the long-term migration pattern could possibly be positively influenced.

To determine household members' willingness for migration, respondents were asked whether there were family members planning to move away from the village within the next 12 months. In the villages with active SHS dissemination, migration tendencies were almost same for SHS household compared to non-SHS households, with on average 15% of respective households stating to have members with plans to move away in the near future. In comparison, the percentage of households with migration tendencies in the control group village without any electricity access was significantly higher with 28%. However, before jumping to conclusions regarding the impact of provided SHS electricity on changes in migration tendencies, the reasons for migration of respective household members have to be considered. Interestingly, of the 31 people with future migration plans, the biggest migration flow (55% of future migrants) was not directed towards the urban centres in Bangladesh, but towards foreign countries such as the Middle East or South-East Asia for employment purposes. Only two respondents stated other migration destinations than foreign countries for employment purposes, namely a small town nearby. Another 32% of migrants were women who had plans for marriage and therefore planned to move to other mostly nearby villages for living together with their husband's family. Only three (7%) of the 31 household members with plans for future migration stated the urban centre of Dhaka as their destination. Two planned to go there for higher education (university), while one woman had marriage plans. It is worth mentioning that all three rural-urban migrants were members of high-income households. In no case were the overall living conditions in general or the absence of electricity in particular the stated reason for migration.

Even though tendencies for migration were revealed to be higher in the non-electrified village, a direct causal relationship between electricity access and migration patterns could not be observed. Most population movement was observable due to migrant labourers working abroad. Rural-urban migration was found to be rather low and mainly limited to individual movements for educational purposes of high-income households. As the impact of SHSs on employment and income generation was already found to be low (cp. section 5.4.1), foreign migration for employment purposes is very unlikely to be affected by SHS dissemination. Furthermore, as the overall living conditions and infrastructure seemed not to be the main reason for household members to leave their village, the overall impact of SHSs on migration can be characterised as marginal.

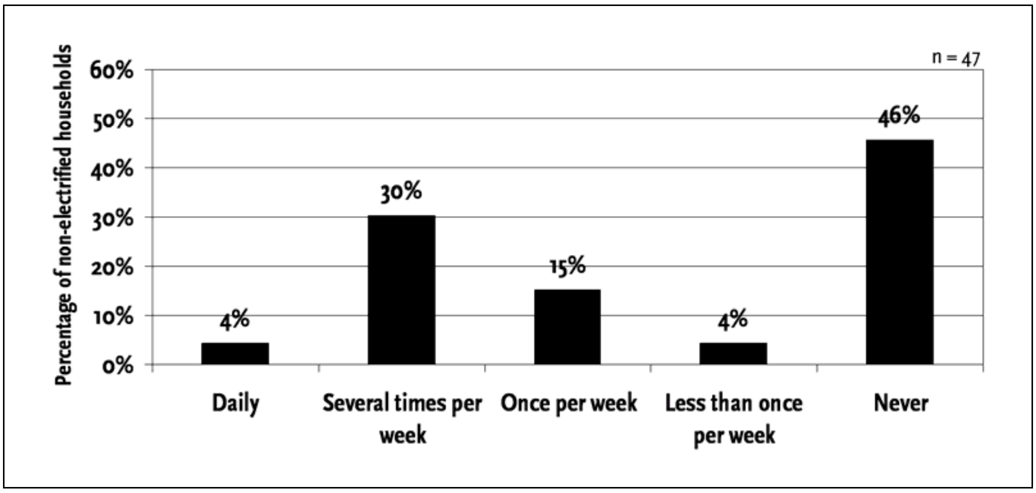
5.4.11 Beneficiaries and indirect impacts

In many cases, past rural electrification studies concluded that mostly wealthier households benefit from electrification programmes, as poorer households cannot afford the initial and running costs of electricity connections. Regarding gender aspects, women are often stated to be the main beneficial group as they are mostly in charge of household-related work and therefore benefit most from electric appliances as well as household lighting. Furthermore, TV and radio access provides women with higher awareness for gender issues such as women's rights or health issues.

Section 5.3.2 revealed an income-related distribution of existing SHSs for the surveyed Bangladeshi villages. SHS use was mainly limited to high and middle-income households. When being directly addressed, 77% of non-SHS households in villages with SHS dissemination stated the high price as the main reason for not having purchased a system.

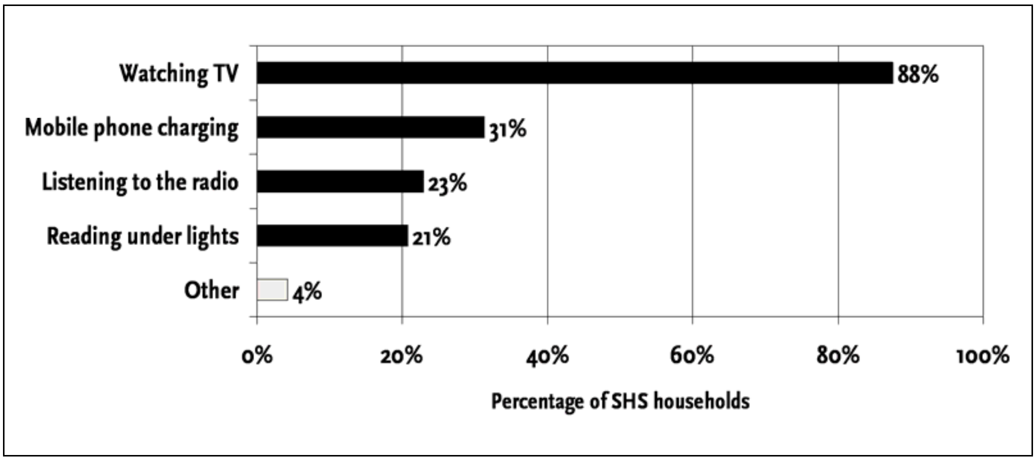
The question is, does this uneven distribution of electricity access consequentially result in the respective socio-economic impacts being equally uneven distributed? The last paragraphs revealed that socialising of neighbouring families in SHS households was a common phenomenon. In fact, 50% of non-electrified households in villages with existing SHSs stated that they visited households with access to electricity at least once per week (see Figure 37). On average, SHS households received regular visits from members of three to four neighbouring non-electrified families. To identify the potential indirect impacts, the household questionnaire included some questions on electricity consuming activities of non-electrified neighbouring families in SHS households. Figure 38 displays the percentage of SHS-owning households stating that the respective activities were regularly conducted by members of neighbouring non-electrified families in the SHS household.

Figure 37: Frequency of visits to households with electricity for members of non-electrified families



Data: Household survey, 2006

Figure 38: Regular electricity-consuming activities of non-electrified households' members in SHS households

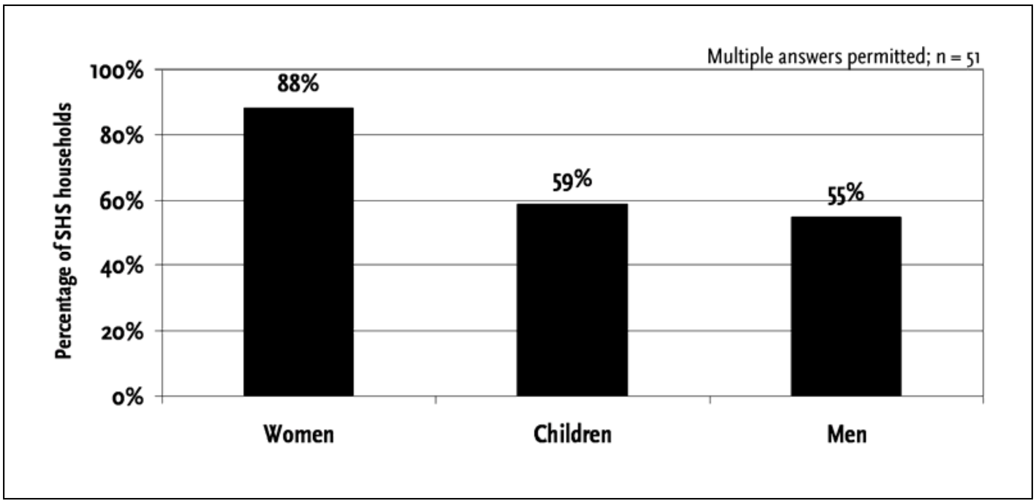


Data: Household survey, 2006

Watching TV was most popular and represented a major attraction for households lacking their own electricity access. For that purpose, 88% of SHS households reported regular gatherings of neighbours in their houses. Especially the impacts related to TV, such as an increase in general awareness as well as an improved knowledge base can therefore also affect households without an own electricity access. Charging of mobile phones and listening to radio programmes were performed by non-electrified neighbours in 31% and 23% of SHS households respectively. Even though not as prevalent as TV watching, the option of charging mobile phones in SHS households can enable even poorer households to use modern telecommunication facilities. In 21% of SHS households, children of neighbouring houses with kerosene-based lighting were regularly allowed to do their reading and studying for school under the electric lights of the SHS, therefore benefiting from improved educational conditions. As previously mentioned, three SHS households allowed families in neighbouring houses to use one of their tube lights for a small monthly fee providing them all mentioned impacts related to electric illumination for a lower price compared to the purchase of a full SHS.

When asked about the household members benefiting most from the SHS (see Figure 39), many respondents referred to all household members benefiting equally. However, women were stated to be the main beneficiary or part of a group of beneficiaries in 88% of SHS households. This figure was 55% for men and 59% for children respectively. The decision to quote women was mostly reasoned by the fact that they worked most of their time at home, thereby benefiting most from improved lighting for household work as well as from avoidance of kerosene-related hassle. Children were stated to benefit from improved conditions for reading and studying.

Figure 39: "Who benefits most from the SHS?"



Data: Household survey, 2006

Summing up, it can be pointed out that even though SHS ownership was mainly limited to middle and high-income households, certain positive impacts seemed to be broader disseminated. As about 50% of non-electrified households frequently visited neighbouring households with SHS, they could also benefit from an increased general awareness and knowledge base from TV, as well as in certain cases from telecommunication facilities (mobile phone charger) and improved lighting conditions for school children. However, about half of the respective village population was currently still not at all affected by positive impacts of SHSs. Women and children were said to be the main beneficiary group in SHS-owning households, as they benefited most from improved conditions for household work as well as from improved lighting for reading purposes.

5.5 Ecological impacts of SHSs

Impact studies on rural electrification generally focus on socio-economic impacts of respective programmes. However, electricity's impact on natural resources is often masked out totally. Changes in the natural environment, however, can have significant influence on human well-being and development, as the 2007 IPCC climate change report drastically demonstrated for the case of global warming (IPCC 2007b: 7-17). Therefore, ecological impacts should be in focus of any sound impact study regarding electrification programmes. In the following, the two most important issues regarding SHSs and the natural environment will be examined: reduction of carbon dioxide (CO_2) gases and battery disposal issues.

5.5.1 Replacement of carbon dioxide

The IPCC climate change report repeatedly 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). As for lighting purposes the use of solar electricity in comparison to kerosene does not produce any direct emissions, a certain amount of savings in the form of CO_2 equivalent is to be expected.

To determine the overall savings of CO_2 emissions from SHSs, replaced emissions from kerosene use as well as emissions resulting from the SHS manufacturing process and transport to the rural areas had to be taken into account. This seemed to be a difficult task, as data on CO_2 emissions from the SHS production process as well as the distribution of SHSs to their place of installation was not available. A detailed analysis of respective CO_2 emissions by POSORSKI at al (2002: 1061), however, came to the conclusion that "Petroleum consumption (...) dominate[s] GHG emissions balances to such an extent that scarcely any importance can be attached to GHG emissions from the transportation and manufacture of SHS. Therefore, it is permissible to use simplified GHG inventories which ignore the GHG emissions arising from the transportation and manufacture of SHS." Thereupon, the analysis was limited to determining kerosene savings as well as respective CO_2 equivalents.

Whereas non-SHS households used on average 3.2 litres of kerosene per month, SHS households had reduced their monthly kerosene consumption on average by 80% to 0.6 litres per month. With a kerosene CO_2 emission factor of 2.4 kg/litre[8], this equals a monthly replacement of 6.24 kg CO_2 equivalent. One SHS in the study area therewith induces emission reductions of about 1.5 tonnes of CO_2 equivalent from kerosene use during its operating life of about 20 years. For comparison, this amount of CO_2 is emitted by one medium size car[9] travelling a distance of about 7,600 km.

5.5.2 Battery disposal

An aspect frequently addressed when relating to potential negative effects of SHS dissemination is the battery disposal practice. As the batteries in use have a limited lifetime, they need to be replaced about every five years. In fact, when referring to the current state of the IDCOL programme in Bangladesh, it is imaginable that an uncontrolled disposal of 100,000 batteries every five years would represent an enormous risk of soil contamination and underground water pollution. Most experts involved in the SHS programmes shared this impression. Throughout the interviews with local SHS experts, potential battery-related waste problems were stated as the only negative impact of the SHS dissemination programme. To limit negative effects on the natural environment, IDCOL has specified for all POs that batteries reaching the end of their lifetime have to be collected from rural customers and returned to the battery manufacturer for recycling purposes. The biggest manufacturer of SHS batteries in Bangladesh – Rahimafrooz – stated to have enough recycling capacity for the total amount of batteries to be returned within the coming years. However, the complete collection of all batteries from the villages is seen as a more challenging task. As most disseminated SHSs are not yet more than five years old, there have been no previous experiences with the willingness of SHS-owners to return their old batteries. To assure complete collection of old batteries, most POs offer small amounts of money for the return of used batteries to their respective offices.

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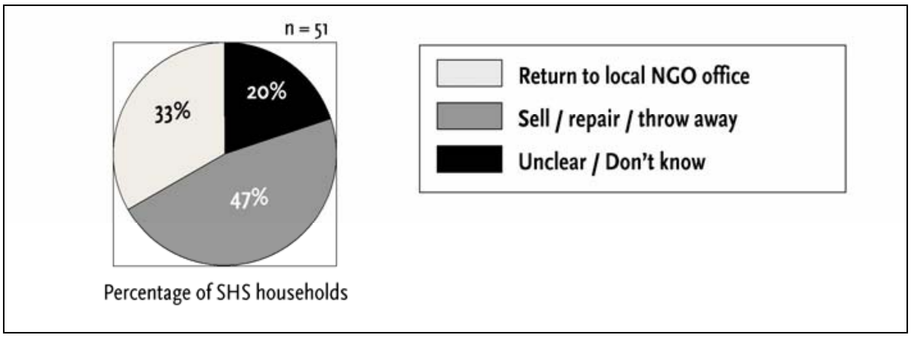
[8] Widely used in similar calculations (KAUFMANN 1999: 11)
[9] Average CO_2 emission: 198 g CO_2/km (AUSTIN et al. 2003: 28)

To assess the risk arising from potential inadequate disposal of batteries in the study area, interviewees in SHS households were asked about their presumable proceeding in case of their battery reaching the end of its operating life. Figure 40 summarises the respective answers given. One-third of respondents indicated to bring back the battery to the NGO's office from which they purchased the system. In this context, it was often pointed out that in case of battery failure before the end of the five-year warranty period, customers would even get a new battery free of cost. In 47% of SHS households, respondents stated battery disposal procedures that were potentially dangerous or environmentally polluting. These included selling the batteries on the local market, trying to "repair" them or just disposing them uncontrolled ("throw them away"). Furthermore, in 20% of SHS households prospective battery disposal practices were still unclear or undecided among the household members.

Figure 40: "When the battery has reached the end of its operating life, what are you going to do with it?"



Data: Household survey, 2006

Even though sufficient battery recycling capacities are in place, future experience will reveal whether the biggest proportion of disseminated batteries will be collected from the rural areas and fed into the recycling system. Results from the household survey showed alarming lack of awareness among rural SHS customers concerning issues of battery disposal. Only one-third of interviewed SHS-owners stated to return their old battery to the respective NGO's rural office. Without increased awareness creation from disseminating organisations among rural customers, this constitutes a high risk of potential threats to people's health and the environment.

5.6 Recommendations for SHS dissemination in Bangladesh

For the future of ongoing SHS dissemination programmes in Bangladesh, it is worthwhile to consider options for the further promotion of positive impacts from SHSs, as well as possibilities of reducing the scale of negative effects. From the findings of the presented field survey, the following recommendations for SHS dissemination programmes can be derived.

5.6.1 Increasing affordability of SHSs

Even though indirect impacts on households without SHS could be observed to a certain extent, the members of SHS-owning households remain the systems' major beneficiaries. About 50% of the non-SHS households can hardly draw any advantage from the existence of SHSs in their village. To reach more parts of the population directly with SHSs, especially households from middle und low-income groups, economic affordability of solar systems should be increased. Therefore, most Bangladeshi SHS experts referred to an **increase in subsidies and financial aids** as well as an **increase in local production of SHS components** to reduce the selling price of SHSs. Whereas an increase of subsidies would disagree with the general notion of reducing external grants and the aim of creating a self-supporting market, the production of SHS components in Bangladesh is already in an advanced stage of planning. For example, IDCOL is currently planning to finance the creation of a local solar panel assembly plant. Furthermore, the **introduction of low-priced Small Solar Home Systems (SSHSs)** with capacities of less than 30 Wp were often recommended, as they might be affordable even to middle and low-income groups. Please refer to Box 3 for some SSHS-related findings from the conducted household survey. GTZ is currently involved in conducting a pilot project regarding the acceptance and feasibility of integrating SSHSs into the ongoing large-scale dissemination programmes. Some of the interviewed households suggested **extending the repayment period** for SHS loans from the current maximum value of 36 months. Thereby, the monthly financial burden could be significantly reduced.

Box 3: The potential of Small Solar Home Systems (SSHSs)

As the dissemination of SSHSs was often described by SHS experts as a sound approach to reach more low and middle-income households, it was attempted to reveal more information on the market potential of these systems. Households without electricity were asked whether they were generally interested in a low-priced solar system. It was pointed out to the respondents that application facilities were limited, i.e. the system could only be used for lighting purposes; TVs or radios could not be operated. Even assumed the interviewed non-electrified household had sufficient financial resources, only 23% stated to be actually interested in purchasing such a system. Most households felt deterred from the absence of TV facilities, to which they attached great importance. Additionally focusing on affordability, it was found that for monthly costs of 100 BDT for a SSHS, 12% of the overall number of households in the two villages with ongoing SHS dissemination would be willing to purchase a system. Increasing the anticipated SSHS price, this figure would be 8% for monthly costs of 200 BDT and 5% for expenditures of about 300 BDT per month. Hardly any SSHS would be sold, if monthly expenditures were as high as 400 BDT.

5.6.2 Promoting positive indirect impacts for non-electrified households

Findings from the household survey revealed that especially low-income households had the least benefit from the development process of the last years. In most cases, these households will not have the financial resources to purchase even a small low-cost SHS. To increase indirect impacts from SHSs especially for these low-income household groups, two different approaches can be recommended: the **dissemination of SHSs in social institutions** as well as the **promotion of 'sharing' existent SHSs' loads with non-electrified neighbours.**

As previously mentioned, utilisation of a SHS can constitute a significant advantage for rural health facilities, e.g. by providing refrigeration facilities. Even without owning a SHS, rural households could thus benefit from a general rise in standard of health services. Even though applications appeared to be limited in rural schools, all school children – irrespective of the family's SHS ownership – could benefit from improved lighting conditions on cloudy monsoon days. The possibility to offer adult education classes in the evening hours may also turn out to be an important benefit for all households in the rural areas. However, for large-scale dissemination of solar systems in social institutions, an important issue is still the question of financing, as respective institutions generally lack adequate monetary resources. More research on respective electricity requirements as well as technical and financial options for solar system utilisation is recommended.

Practices such as allowing neighbours to watch TV and charge mobile phones, or sharing one tube light with a nearby family, can already be observed in SHS households. However, there are still many families that do not have this option offered. The staff of SHS-disseminating organisations could possibly promote the idea of 'sharing' electricity with non-electrified neighbours by pointing out additional income possibilities through lending a light or offering mobile phone charging services for a minimal fee. That way, households being previously without electricity could benefit from basic electric applications such as lighting or mobile phone charging for significantly lower expenditures than in the case of purchasing an own system. This practice is already in place for shops and small businesses covered in the 'micro utility' model of Grameen Shakti, where rural entrepreneurs are motivated to sell electricity to other shops and businesses of the local bazaar. Grameen Shakti is also promoting the operation of village pay phones ('Polli Phone'), mainly run by women. They offer telephone facilities for a small fee and therewith create income of up to 7,000 BDT per month (Barua 2005: 7-8). Expansion of equivalent approaches is highly recommendable.

5.6.3 Promoting productive use of electricity

The findings of the household survey revealed that income-generating activities were not found to be stimulated by the availability of solar electricity. In the few cases of electricity use, its application was limited to illumination of productive activities. To promote the increased use of electricity for productive purposes, the **development of low-voltage household appliances** depending on household demand, such as blenders or sewing machines, is conceivable. In combination with integrated **training** on skills such as sewing or handicraft production, an increase in income-generating activities might be thinkable. Further research and development in related technical and socio-economic issues is recommended.

The use of electricity in poultry farms appeared to be a beneficial factor for overall productivity. In some cases, car batteries were found to be used for lighting purposes. However, the **utilisation of SHSs in poultry farms** still appeared to be rather low. Therefore, organisations involved in the SHS dissemination process should increasingly include poultry farmers as a target group of their promotional activities. For the case of **shops and businesses** in local bazaars, results were mixed. While SHS users reported a rise in customers and income as well as diversification of offered services, shops without SHS stated a decline of their customer base. While the dissemination of SHSs in shops and businesses is ongoing, it is recommended that further detailed research be conducted and records of respective developments be kept.

5.6.4 Awareness building for battery disposal issues

As previously mentioned, uncontrolled battery disposal constitutes a serious threat to environmental sustainability of the ongoing SHS dissemination programmes. The conducted household survey revealed rural households' lack of awareness regarding appropriate battery disposal practice. Therefore, the author strongly recommends the **implementation of awareness campaigns**. IDCOL as well as participating donor agencies should put emphasis on the importance of a functioning battery collection and recycling system. In this regard, **monitoring of returned battery numbers** should have high priority.

5.6.5 Other recommendations

As it seemed very likely that village B might become connected to the national grid within the near future, many households abstained from spending significant amounts of money to purchase a SHS. This seems understandable, as potential long-term monetary benefits (cp. section 5.4.2) from the SHS will not arise for the respective households if they switch to grid electricity after a couple of years. For the case of increased future reliability of grid electricity supply, the author recommends that **SHS dissemination activities be limited to areas where it is very unlikely that grid electricity access will be available** in the next 10 to 15 years. However, as some Bangladeshi SHS experts noted, planning reliability of grid extension measures in Bangladesh is insufficient. Hence, it is often problematic to definitely predict future developments regarding grid extension.

The household survey revealed TV watching to be one of activities most frequently conducted throughout the evening hours. Even though educational programmes were already quite popular, knowledge about their existence could possibly be increased. To broaden benefits from media consumption, pilot **awareness and advertising cam-**

paigns for the increased use of educational TV and radio programmes could be implemented. These could possibly lead to more frequent utilisation of respective programmes and a more sensible exposure to media.

Most SHS households stated the limited power supply of the SHS as their main disadvantage. Respondents often suggested **offering systems with a higher potential load and battery storage capacity** to be able to run appliances such as ceiling fans or colour TVs. 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.

6 Conclusions

Rural electrification is a common approach of international development programmes to provide the rural population of developing countries with improved energy services, thereby promoting Sustainable Development. In the last few years, the use of Renwable Energy Technologies (RETs) has gained growing importance, especially in areas where the extension of national grid lines is not an economically viable option. The use of solar photovoltaic (PV) technology, Solar Home Systems (SHSs) in particular, is increasingly promoted. Compared to other stand-alone systems, its large-scale commercialisation has proven very successful in several country cases such as in Bangladesh where already more than 100,000 SHSs have been disseminated in the last years.

The following sections will give recommendations regarding methodological approaches for impact assessments of rural electrification programmes (section 6.1) and summarise and compare findings regarding impacts of grid electrification as well as SHS in Bangladesh (section 6.2). Section 6.3 will assess the potential of SHSs for promoting Sustainable Development in rural Bangladesh, while section 6.4 will reflect on the possibilities of drawing general conclusions from the investigated Bangladeshi case, in regards to the impacts of SHSs in the developing world.

6.1 Methodological recommendations

Analysis of former studies investigating impacts of rural electrification programmes in certain cases revealed applied methodologies that were found to be inadequate for drawing conclusions regarding electricity's socio-economic impacts. Correlations alone are not a sound approach of proving economic and social benefits arising from electricity. They ignore the complex interrelations between socio-economic development and access to electric energy, which just as well comprise influences of socio-economic conditions on the electricity diffusion process. Therefore, existing impact studies should always be critically assessed concerning their applied methodologies.

The Bangladesh survey constitutes a good example. While the income-dependent distribution of SHS could be interpreted as a result of solar electricity contributing to an increase in income of rural households, comparison with further qualitative[10] as well as quantitative[11] findings disagreed with this perspective. It was instead the amount of available financial resources that determined the availability of a SHS in the respective rural households.

To make credible assumptions on the impacts directly affected by electricity, scientific studies therefore should critically investigate direct linkages and include an adequate amount of qualitative information on causal relationships. A mix of quantitative methods and qualitative approaches and comparing respective results is highly recommendable.

6.2 Impacts of electricity – summary of findings

When it comes to socio-economic impacts of electricity, case studies are numerous for the case of grid electrification. Results, however, can vary significantly and not all benefits of electricity could be verified for every existing rural electrification programme. Implementation strategies, financing mechanisms, accompanying measures (e.g. trainings, awareness campaigns) as well as the social, economic, and cultural background seem to be very important factors influencing the impacts of electricity for rural consumers. For the case of SHS electrification in Bangladesh, preconditions for socio-economic impacts are quite different from grid-based approaches as provided loads and therewith application options are limited and the commercial dissemination involves high costs for the customers. Respective impacts have been investigated through a broad field survey by the author of this thesis. The impacts most frequently observed for grid electricity in the seven case studies as well as for the case of SHSs in Bangladesh are summarised in the following (cp. Table 8).

Income of rural households was frequently found to be positively influenced by electricity supply from the national grid. Electric power provided benefits for the employment situation and productivity of rural industries, commerce, household

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[10] Many non-SHS households stated that the high costs were the main reason for not purchasing a system

[11] Only two SHS households were using electricity for income-generation

production, and agriculture. In sharp contrast, the impact of SHSs on Bangladeshi households' income was observed to be quite limited, as electricity was hardly ever used productively. The missing necessity of additional income for affluent SHS households as well as the non-availability of electric appliances were found to be the main reasons for this situation. Commercial usage of SHS was limited to small shops and businesses in local markets, which stated significant benefits for their businesses resulting in higher income.

Even though not observed in all rural electrification programmes, monetary savings resulting from reduced lighting expenditures were sometimes cited for the case of grid electrification. However, due to the high monetary efforts for Bangladeshi families to purchase a SHS, even though kerosene expenditures were reduced, in most cases overall costs of the SHS did not amortise. Financial savings were therefore not observed.

Due to the use of household appliances (e.g. blenders), grid electricity in certain cases was found to reduce women's workload or improve overall working conditions (e.g. through the use of electric lighting). As compared to grid connections, electric power from SHS is rather limited, the use of household appliances and a therewith-connected quantitative reduction of workload could not be observed in Bangladeshi SHS households. However, especially women quoted improved conditions for household work due to electric lighting and avoidance of kerosene-related work.

Electric lighting and the availability of new forms of entertainment media were identified as factors leading to prolonged evening hours of household activity in households with access to national electricity grids. Watching TV, productive activities and the studying of school children were frequently cited to be common activities benefiting from the availability of extra time. These findings could also be confirmed for SHS use in Bangladesh, except for the lack of productive activities (see above).

As observed for grid connections, electricity can provide improved conditions for education as it can lead to improved services of rural schools (lighting, teaching aids) as well as longer studying hours for children in electrified households. The survey in Bangladesh, in line with previous findings for grid electrification, revealed extended studying time for children due to the availability of electric lighting. However, hardly any improvement in educational institutions was observed, as SHS dissemination was nearly entirely limited to households and businesses. If available in rural schools, solar electricity was mainly used for lighting purposes.

Direct benefits for health in rural households, e.g. due to reduced kerosene fumes, were frequently cited but seldom proven by any of the analysed study reports on grid electrification. However, the overall health situation was stated to benefit from better performance of rural health institutions (lighting, refrigeration, electric equipment) as well as the availability of health-related information through TV and radio. In Bangladesh, solar-electrified health institutions were not yet very prevalent, even though there seemed to be a high potential for the use of vaccine refrigerators. Improved indoor air, increased availability of information on health issues, as well as reduced accidents related to kerosene use could be observed for SHS-using households.

Usage of radio and TV was frequently stated as a major impact of grid electrification, as it provided increased possibilities for information, education, and entertainment. This was also the case in Bangladeshi SHS households, where the use of black and white television sets was very common.

Across the board, most studies identified an improved feeling of safety in households with electricity from national grids due to the availability of improved illumination from household as well as public lighting, especially the latter leading to a potential increase in the electrified communities' social activity. As in Bangladesh, solar PV technology was not used for public lighting, an improved perception of safety could only be observed in households owning a SHS. Still, there seemed to be an increase in social activity due to social gatherings taking place more frequently in households with electric lighting and TV facilities.

Even though often discussed, most studies on grid-based rural electrification could not find any evidence for a decrease of rural-urban migration due to the availability of electricity. This was also the case for SHS in Bangladesh, where households with SHS did not show higher migration tendencies than households without electricity.

Table 8: Impacts identified for grid electrification and SHS dissemination in Bangladesh

Impacts		Grid electricity*	SHS in Bangladesh
Income / Production	Industries & businesses	▪ Increased employment ▪ Increased productivity ▪ Increased income	▪ Increased income (small shops & businesses)
	Household production	▪ Increased productivity ▪ Increased income	-
	Agriculture	▪ Increased productivity ▪ Increased income	-
Energy expenditures		▪ Reduction of household energy expenditures (mixed findings depending on country context)	-
Household workload		▪ Reduction of women's workload ▪ Improved working conditions	▪ Improved working conditions
Time use & length of day		▪ Prolonged household activity in the evening: watching TV, productive activities, children's studying	▪ Prolonged household activity in the evening: watching TV, household work, children's studying
Education		▪ Use of electric lighting in rural schools ▪ Use of electric teaching aids in rural schools ▪ Longer studying hours of school children	▪ Use of electric lighting in schools ▪ Longer studying hours of school children
Health		▪ Use of electric lighting in rural health centres/hospitals ▪ Use of vaccine refrigeration in rural health centres/hospitals ▪ Use of electric medical equipment in rural health centres/hospitals ▪ Health-related information (TV/radio) ▪ Reduced indoor air pollution	▪ Use of electric lighting in rural health centres/hospitals ▪ Use of vaccine refrigeration in rural health centres/hospitals ▪ Health-related information (TV/radio) ▪ Reduced indoor air pollution
Information & Entertainment		▪ Use of TV/radio: improved conditions for information, education, entertainment	▪ Use of TV/radio: improved conditions for information, education, entertainment
Perceptions of safety & social activity		▪ Increased feeling of safety due to household illumination ▪ Increased feeling of safety due to public lighting ▪ Increased social activity	▪ Increased feeling of safety due to household illumination ▪ Increased social activity
Telecommunication		Not investigated	▪ Improved options for utilisation of mobile phones (mobile phone charging)
Ecological impacts		Not investigated	▪ Reduced CO_2 emissions ▪ Need for save battery disposal

*summary of results from seven impact studies (see table 2)

The Bangladesh survey could detect another impact of electricity that is just recently becoming increasingly important. Due to the widespread ownership of mobile phones, electricity from SHS is becoming an essential factor for telecommunication in remote rural areas, where it constitutes the only energy source to charge the phones.

Ecological impacts were not the focus of most grid-based electrification programmes. However, for the case of SHS in Bangladesh, reductions of carbon dioxide (CO_2) emissions could be observed in comparison to former utilisation of kerosene for lighting purposes. As most national grids in developing countries are still mainly powered by fossil energy carriers such as coal, oil, or gas, this constitutes an important advantage of the solar PV technology. The disposal of batteries constitutes the only potential negative impact of SHSs which therefore should be closely monitored.

When it comes to beneficiaries of electricity access, most of the analysed studies stated that grid electricity seems to favour wealthier households, as they had fewer problems purchasing a connection compared to low-income households. On household level, women and children were mostly stated to benefit most from household electricity connections as they spent most of their time within household premises using electric lighting and household appliances. Compared to findings regarding grid connections, the distribution of SHSs in Bangladesh seemed to be even more uneven. Even though micro financing options were offered, the financial effort to purchase a solar system was significantly higher compared to the cost of a grid connection. Therefore, ownership of SHSs was mainly limited to the wealthiest households of the community. However, at the same time the field survey revealed a high number of non-SHS households benefiting indirectly from TV, mobile phone charging and studying facilities in SHS households. Even though household appliances were not in use, women and children were still found to be the main beneficiaries in households with SHS, as they reported improved working and studying conditions due to electric lighting.

6.3 SHS and Sustainable Development in rural Bangladesh

To be able to assess the influence of SHSs on sustainable rural development in Bangladesh, the impacts identified in chapter 5 were assigned to the three aspects of sustainable development, namely 'economic growth and equity', 'social development' and 'conserving natural resources and the environment' (cp. Box 1). Table 9 summarises the results. It clearly indicates that most positive impacts from SHS on sustainable development are based in the social dimension.

Economic growth was mainly facilitated through higher incomes of shops and small businesses using SHS for improving their business activities. However at the same time, the uneven distribution of SHS in shops and businesses might intensify the unequal distribution of financial resources between wealthy and poor businessmen. Therefore, not all social groups might benefit equally from economic growth facilitated by SHSs. Regarding the general framework of economic growth, improved education and health of the rural population can provide significant improvements in skills and productivity of the rural labour force. Within the scope of long-term economic development, SHS might therefore induce indirect stimulations for future investment in rural areas.

Table 9: Impacts of SHS promoting/restraining aspects of Sustainable Development

Aspect of Sustainable Development	Promoting (+) and restraining (-) impacts of SHS
Economic Growth and Equity	+ Increased income of shops and businesses + Supportive environment through good education/health - Beneficiaries limited to affluent businesses/households
Social Development	+ Improved working conditions + Improved conditions for education + Improved health-related conditions + Improved information flow + Improved entertainment facilities + Improved telecommunication facilities + Increased perception of safety + Increased social activity - Beneficiaries limited to affluent households
Conserving Natural Resources / Environment	+ Reduced CO_2 emissions - Potential environmental threats of battery disposal

Compared to influences on economic development, the SHSs' direct impacts on social development seem more dramatic. Factors like improved conditions for education, health, and household work, as well as an increase in information, communication, entertainment, and social activity constitute radical changes for the traditional social life in rural areas of Bangladesh. Many households stated that their lifestyle had significantly improved due to the availability of solar electricity. However, as it was already noted for economic benefits, social impacts were mainly limited to high-income households. In the long-term, this could contribute to widening the social gap between high and low-income members of the rural communities. As this issue has already been recognised by SHS-disseminating organisations, it is likely that there will be a tendency to offer more financially attractive SSHSs to middle and low-income households. Nonetheless, the poorest families will still not be able to afford such a system.

The dissemination of SHSs in Bangladesh is actively contributing to conserving natural resources and the environment, as it reduces CO_2 emissions through the saving of kerosene consumption. On the other hand, old batteries might represent a serious threat to natural resources. This threat, however, can be significantly reduced by introducing a reliable battery recycling system.

Concluding, this thesis revealed that SHSs had significant positive impacts on sustainable rural development in Bangladesh. Even though economic benefits were limited, the positive social changes in rural village life became obvious. In the long-term, some of the social benefits, such as improved education or health, might even create a supportive environment for further economic growth. Assuming that battery disposal issues are solved in the future, SHSs will not negatively influence the natural environment, but will even contribute to a reduction of the atmospheric CO_2 concentration.

Compared to electricity from the national grids, the scope of impacts was found to be more limited for SHSs in Bangladesh, especially regarding economic aspects. Nonetheless, in remote places lacking access to national grid lines, SHSs constitute a reasonable option for rural electricity supply particularly promoting aspects of social development. Even though a 'big push' for rural development solely through the utilisation of SHS cannot be expected, their application seems to be favourable in combination with other interventions of comprehensive rural development programmes, such as projects in the fields of business development, education, health, or gender.

6.4 Applying Bangladesh-related findings to other country cases

Following the verification of the impacts of SHSs for the case of Bangladesh, can we draw general conclusions for SHS-related impacts, even for electrification programmes in other parts of the world?

Given adequate affordability and distribution of SHSs, some of the impacts can surely be directly applied to other SHS dissemination programmes, as they are directly connected with electricity and virtually independent from other external factors. Impacts directly related to electric lighting are very likely to be assigned to this category, as electric lights constitute a basic element of all SHSs around the world. These impacts include improved income of shops/small businesses due to increased customer attraction, improved conditions for household work in the evening, extended hours of daily activity, reduced indoor air pollution, an improved feeling of safety, and increased social activity. Even though minor differences between country cases might be observable due to different cultural habits, these impacts are very likely to occur in all households/businesses owning SHSs. Besides lighting-related benefits, impacts affecting the natural environment, such as the reduction of CO_2 emissions and battery-related disposal issues, are probably also generally applicable to all SHS dissemination programmes.

Other impacts of SHSs cannot be generalised that easily. Even though observed for some country cases, increased household income due to productive use of solar electricity, for instance, was virtually non-existent in rural Bangladesh. This impact seems to be dependent on SHS owners' need for additional income generation, awareness about electricity's respective potentials, as well as the availability of productive appliances and machinery suitable for utilisation with SHSs.

Monetary savings due to reduced energy expenditures were not identified in the case study of Bangladesh. Still, there seems to be a potential for such savings in other country contexts. Conditional factors might involve the price and amount of formerly utilised lighting fuels, as well as initial and running expenses for the SHS (heavily depending on applied financing mechanisms and subsidy schemes) and periodic battery replacements.

Improved conditions and time savings for household work can be achieved by the utilisation of household appliances. In Bangladesh, household appliances for SHSs were unavailable, neither in the market nor from SHS-disseminating organisations. Given some technical research and appropriate marketing approaches, however, it might be thinkable that small appliances such as blenders could be disseminated in Bangladesh as well as in other country contexts.

The survey in Bangladesh revealed improved conditions for studying of school children as well as an increase in studying hours in SHS households. It seems to be very likely that this benefit could also be observed in other SHS households around the world, however, without schools and studying material, electric lighting alone cannot result in improved education. As a prerequisite, there have to be sufficient numbers of schools available and families need to have the financial resources to be able to send their children to school and provide them with educational books.

Significant benefits arising from the use of TV and radio have been identified for the case of Bangladesh. Two factors will have major influence on whether these benefits will be applicable to other SHS programmes. Foremost, TVs/radios have to be available and should be affordable to SHS household. Furthermore, educational and health-related benefits heavily rely on the availability of respective TV/radio programmes.

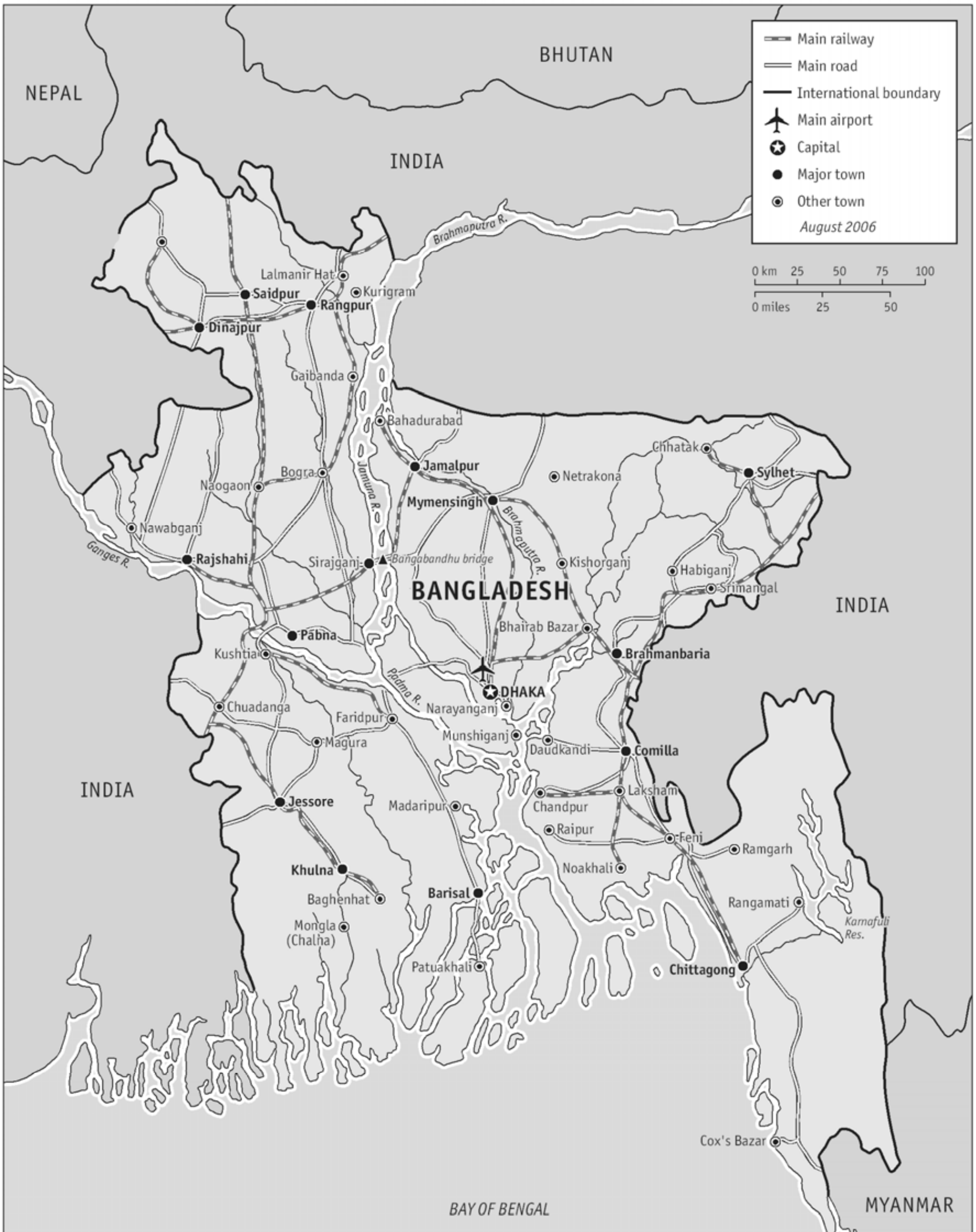
The improvement of rural educational and health facilities due to SHS use was found to be still scarce in rural Bangladesh. The potential of SHSs to improve this kind of social infrastructure in rural areas of developing countries is highly dependent on the degree of government involvement and financing, as the rural institutions themselves mostly have very limited financial resources available.

To improve mobile communication facilities by using SHSs, a mobile network with good coverage of rural areas is an absolute necessity. Low-cost mobile phones and tariffs that are affordable to rural customers have to be available. Furthermore, mobile phone chargers adapted to operate with SHSs have to be widely available through the market or SHS disseminating organisations.

Recapitulating, some impacts of SHSs, especially those directly and exclusively related to electric lighting, are very likely to be observable in most SHS dissemination programmes, assumed that the systems are affordable to rural customers. Other potential impacts are highly dependent on the socio-economic and SHS programme context. Therefore, the findings from this study can only in part be transferred to other SHS dissemination programmes. Country and programme-specific assessments of social, economic, and ecological impacts of SHSs are essential.

Appendices

A1 Map of Bangladesh



Source: EIU 2007

A2 Background information on Bangladesh

Bangladesh is located in South Asia on the eastern flank of India between 20 35' and 26 75' north of the equator and between 88 3' and 90 75' East (ER RASHID 2005: 15). It shares more than 4,000 km of border with India. In the extreme southeast, Bangladesh's neighbour is Myanmar. The southern boundary forms the Bay of Bengal. With a total area of 144,000 km² Bangladesh as a country is relatively small being twice as large as Sri Lanka, but only half as big as Italy (HOSSAIN et al. 2006: 5). The climate can be classified as tropical with temperatures seldom below 7 degrees Celsius and abundant sunshine throughout the year. The tropical monsoon climate provides a distinct warm, rainy season from June to October, mild winters from October to March, and hot, humid summers from March to June (ER RASHID 2005: 13, CIA 2007). Bangladesh contains most of the vast delta of the Ganges and Brahmaputra river system. Around 25,000 km² of Bangladesh can be classified as deltaic, 10,000 km² are permanently covered with water (ER RASHID 2005: 17, HOSSAIN et al. 2006: 5). During the rainy season, flooding is a regular phenomenon with more than half of the country regularly remaining under water, and cultivation being restricted to higher grounds. The major part of this water originates from rainfall as well as melting snow from the Himalayas (HOSSAIN et al. 2006: 5).

With a total area of 144,000 km² and a population of about 147 million Bangladesh is among the world's most densely populated countries (CIA 2007, EIU 2007: 14). The population growth is decreasing, but with an annual growth of 1.3% still high. The urban population is growing twice the overall population growth rate and now accounts for 23.4% of the total population. The capital und principal population centre is Dhaka, with 9.9 million inhabitants being one of the largest cities in the world. Within the next decade, Dhaka is estimated to reach a population of 22.8 million people. According to the 2001 census, 90% of the population were Muslim, 9% Hindu and the remainder mainly Buddhist or Christian (EIU 2007: 14).

55.3% of the country contains arable land, from which 47,000 km² are irrigated (CIA 2007). Rice is the principal crop covering 79% of the total cropped area, some land being double or triple cropped. Other important crops are wheat, jute, potato, oilseeds, pulses, tobacco, cotton, sugarcane, fruits, and vegetables. Fisheries, livestock, and poultry are other important sub-sectors of Bangladeshi agriculture with a big proportion of the rural population involved in respective activities (ISLAM n.d., HOSSAIN et al. 2006: 5). Bangladesh has virtually achieved food self-sufficiency and has diversified the crop base. However, unpredictable climate conditions such as flooding and droughts regularly undermine production plans and targets, disrupting the economy and necessitating food imports (EIU 2007: 23). Although only accounting for some 20% of the GDP, nearly two-thirds of the Bangladeshi population are employed in the agricultural sector (CIA 2007).

Historically, the manufacturing sector has been mainly involved with processing domestically produced agricultural raw materials. In the late 1980s, industrial activities expanded into new areas such as ready-made garments and fertiliser manufacturing (EIU 2007: 33). Today, industrial production in Bangladesh mainly consists of cotton textiles, jute, garments, tea processing, cement, chemical fertilisers, light engineering and sugar industries. Most of the required intermediate inputs for the manufacturing sector are imported, particularly in the garment sector, limiting the value added in the domestic production process. Industrial activities are mainly centred around the country's major cities, Dhaka and Chittagong (EIU 2007: 23). Manufacturing contributes 21% to the GDP with only 11% of Bangladeshis involved in this sector (CIA 2007).

In many developing countries, the biggest part of the GDP is generated through services, in many cases in the informal sector. This is also true for Bangladesh with an estimate of 60% of the GDP made up by services and 26% of the population mainly involved in sectors such as transport, trade, construction, and housing (CIA 2007, ER RASHID 2005: 50).

More than 250,000 Bangladeshis work abroad, mainly in the Middle East and Saudi Arabia. Remittances are an important source of income for an increasing number of Bangladeshi households. Substantial inflows of remittances are crucial to Bangladesh's macroeconomic stability, as they have traditionally offset a large proportion of the country's trade deficit and its services and income account deficit (EIU 2007: 15).

Bangladesh's main import products are machinery and equipment, chemicals, iron and steel, textiles, foodstuffs, petroleum products, and cement. Major goods for export are garments, jute and jute goods, leather, frozen fish and seafood. The trade gap is widening with a value of overall imported goods of $13.77 billion compared to exports in the size of $11.17 billion. External debts have added up to $22.55 billion in 2006 (CIA 2007).

For nearly two decades the GDP has been growing steadily about 5% per year (5.4% for 2004/05), following a rapid liberalisation in the 1990s (EIU 2007: 28). The estimated 2006 GDP is $331 billion (PPP - purchasing power parity) and GDP per capita is $2,200, which is low compared to other developing countries of South Asia such as Sri Lanka with $4,600 or India with $3700 but still slightly higher than the per capita GDP in Nepal, which is stated at $1500 (CIA 2007).

The biggest drawbacks for the Bangladeshi economy are frequent cyclones and floods, inefficient state-owned enterprises, inadequate port facilities, a rapidly growing labour force that cannot be absorbed by agriculture, delays in exploiting energy resources (natural gas), insufficient power supplies, and the slow implementation of economic reforms (CIA 2007).

The Bangladeshi administrative system divides the country into six divisions. These are Dhaka, Chittagong, Khulna, Barisal, Rajshahi, and Sylhet. These divisions are further divided into 64 districts, each with its own district council. Beneath the districts are 460 subdistricts (Thana/Upazila) and 4,484 rural union councils, which are currently the lowest tier of government in Bangladesh (EIU 2007: 8). The political constellation is difficult. Political infighting and corruption at all levels of the government is a major hindering of the country's development. Bangladesh ranks 156 of 163 countries in the corruption perceptions index 2006 (Transparency International 2006: 7). In theory, there exists full political freedom, but in practice, due to a culture of intimidation and sometimes secret killings, most opposition is muted (HOSSAIN et al. 2006: 7-8).

The state of human development is low. Since 1974, Bangladesh belongs to the group of 50 least developed countries identified by the United Nations on criteria such as low-income, human resource weakness and economic vulnerability (UN-OHRLLS n.d.). With a human development index (HDI) of 0.530 Bangladesh ranks 137 of 177 countries (UNDP 2006b). The number of people below the poverty line was reduced from 58.8% percent in 1990 to 49.8% percent in 2000, despite a rise in inequality with the overall Gini coefficient rising from 0.259 in 1992, 0,451 in 2000 to 0.467 in 2005 (UN and the Government of Bangladesh 2005: 5, AHMED et al. 2006). Widespread starvation has practically disappeared. However, instances of near starvation do prevail in certain parts of the country especially at times when agricultural work is not available (HOSSAIN et al. 2006: 5-6).

According to a 2003 estimate, 43% of the population over the age of 15 are literate, i.e., are able to read and write. By this definition, only 32% of the female population and 54% of male population are literate (CIA 2007). Literacy rates in rural areas are generally lower than those in urban areas (UN and The Government of Bangladesh 2005: 13). Primary education is free, however fewer than half of all children complete the five years of primary schooling. The poor quality of elementary education is attributable to badly trained or absentee teachers, large classes and a shortage of books. Educational attainment for girls was among the lowest in the world until the early 1990s. Today Bangladesh is among the leaders in girl's education, according to the World Bank. Much of the improvement is the result of a stipend programme launched by the government in 1993 to support female secondary education (EIU 2007: 16).

The health situation in Bangladesh is deficient. Life expectancy at birth is 62 years. The infant mortality rate is 61 deaths per 1,000 live births (CIA 2007). People frequently suffer from infectious diseases and malnutrition is still a common problem. In 61 of 64 districts, cases of arsenic poisoning due to contaminated groundwater are prevalent. At least 200,000 people are suffering from arsenic-linked diseases. However, the proportion of underweight children fell from 66% to 48% between 1990 and 2004. Access to medical services is more limited in Bangladesh than in neighbouring countries. Only 13% of births were attended by skilled health personal in the period between 1996 and 2004. Government health services are generally poor. Poor-quality and poorly regulated private clinics have proliferated in both urban and rural areas. Non-governmental organisations (NGOs) have also been providing health services (EIU 2007: 16-18).

A 2005 investment climate assessment by the World Bank identified poor-quality and poorly managed infrastructure as one of the major deficiencies in Bangladesh's investment climate. Road connectivity within the country is poor and unreliable. That said, some progress has been made in recent years, and Bangladesh's transport road infrastructure has improved now connecting every district and subdistrict administrative centre, even those in remote areas. Besides the roads, the waterways are besides the roads the most important transport facility. Bangladesh has due to its natural preconditions one of the largest inland waterway networks in the world. However, improvements to waterways including more dredging programmes, better boat safety regulations and the privatisation of some of the ferry and cargo routes are necessary. Bangladesh's telephone density is the lowest in South Asia and one of the lowest in the world. However, it rose from 1 per 100 people to 9 in the past five years. In contrast, the mobile phone industry has grown rapidly in recent years. The mobile phone density rose from 1% in 1997 to 6.7% at the beginning of 2006 (EIU 2007: 18-21).

A3 List of conducted qualitative interviews

Date	Name	Position
September 4, 2006	Mr. Ruhul Quddus	General Manager, Rural Services Foundation (RSF)
September 5, 2006	Mr. Mohammad Raihan Habib	Senior Investment Officer, Infrastructure Development Company Limited (IDCOL)
September 7, 2006	Mr. Abdur Razzaque	Director Renewable Energy, Rural Electrification Board (REB)
September 7, 2006	Dr. Muhammad Ibrahim	Executive Director, Centre for Mass Education in Science (CMES)
September 11, 2006	Prof. Dr. M. Rezwan Khan	Vice Chancellor, United International University (UIU)
September 13, 2006	Mr. Abser Kamal	General Manager, Grameen Shakti (GS)
September 17, 2006	Mr. Sazzad Hossain	General Manager, Rahimafrooz Solar
September 18, 2006	Mr. Sudip Kumar Saha	Solar Programme Manager, Bangladesh Rural Advancement Committee (BRAC)
September 19, 2006	Dr. N.C. Bhowmik	Director, Renewable Energy Research Centre (RERC), University of Dhaka

A4 Guideline questionnaire used for qualitative interviews

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General Information on Interviewee

1. What is the role of your organisation regarding the dissemination of Solar Home Systems (SHS) in rural Bangladesh?

2. What is your position, role and task in your organisation?

Rural Development in Bangladesh

3. What are the main problems households in rural Bangladesh have to cope with?

4. How could these problems possibly be solved?

5. What is rural development for you? How would you define rural development?

6. What are key preconditions that have to be met to enable rural development in rural Bangladesh?

7. What is the role of electricity for rural development in rural Bangladesh?

SHS and general socio-economic impacts

8. What are major advantages and disadvantages of the SHS technology compared to other forms of electricity supply available in rural Bangladesh? What other technological options do exist to provide electricity to rural areas of Bangladesh?

9. What is the electric power provided by the SHS mainly used for in rural households?

10. In what ways do SHS contribute to rural development? What are the positive impacts of the SHS dissemination on the economic and social conditions in the respective villages?
Economic impacts:
Social impacts:
Is Migration affected?

11. Can also negative impacts on the socio-economic conditions in the villages be observed? What kind of negative impacts?

12. Are there any strategies to reduce these negative impacts?

13. What share of households is typically equipped with a SHS after a certain period of SHS dissemination in a village? What is the average maximum share of households you can currently reach by SHS in a village?

14. It is sometimes discussed that with SHS not all parts of the rural population can be reached with electricity. For instance poorer households often cannot afford the costs of a system even when micro financing is offered.
Do you agree with this statement and how from your point of view how could this problem be solved?

15. In villages with several SHS already installed, what specific positive and/or negative indirect impacts on households without SHS can be observed?

2

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16. Are there any social institutions like schools and hospitals equipped with solar panels by the programme run by your organisation? What positive and/or negative developments can be observed after installing the systems in the respective institutions?

17. Are there any experiences with the combination of SHS and IT education? Adult Education? Where?

Income-generating activities

18. What fraction of the disseminated SHS is used for income-generating activities?

19. What are the main productive uses in businesses and households?

20. What type of households ('wealthier' or 'poorer') use SHS more often for income generation?

21. Sometimes longer opening hours of businesses achieved by lighting are mentioned as a possibility for higher income, although it is questionable whether these longer opening hours lead to higher expenditures of the customers in the village. What is your opinion regarding this matter?

Sustainability and future of SHS dissemination

22. Regarding ecological impacts the used batteries are the crucial factor. What is done with batteries that have reached the end of their life-span?

23. What is done to guarantee sustainable functioning of the disseminated SHS? What about after-sale service? Service after the three year pay-back period?

24. What are the biggest problems that your organisation has to cope with regarding the SHS dissemination?

25. How could these problems possibly be solved?

26. IDCOL receives international funds to provide different kinds of subsidies to the Bangladesh PV sector. How would you further develop/improve these different subsidy schemes? Is the PV sector mature enough to continue its expansion without or with reduced subsidies? Could some or all of the subsidies be shifted to other/new products?

27. What future plans does your organisation have regarding SHS?

Thank you very much for taking the time for this interview!

3

A5 Household survey – questionnaire type 1

Questionnaire on socio-economic impacts of rural SHS electrification

Household Type 1 – Household with electricity from one of the following sources:
- ☐ Solar Home System (SHS)
- ☐ Storage Battery
- ☐ Generator (Diesel)
- ☐ Electricity bought from neighbour
- ☐ Other source

Basic Data Questionnaire

Interviewer:

Name	
Sex	☐ male ☐ female

No. of questionnaire	
Date	
Village	
Name of Family	

Village Type:
(Please tick one)
- ☐ Village with SHS disseminated
- ☐ Village without SHS disseminated

Main Interviewee:
(Please tick one)
- ☐ head
- ☐ spouse
- ☐ (other household member: name: ______ age: ______ relation to household head: ______)

1

Households Structure

1.) Please complete the following table for household head and spouse:

	Name	Sex	Age (years)	Marital status (Please tick one)	How many years of schooling completed? (Enter the years, 0 no schooling)
Household Head		☐ male ☐ female		☐ Single ☐ Married ☐ Divorced ☐ Widowed	
Spouse		☐ male ☐ female		☐ Single ☐ Married ☐ Divorced ☐ Widowed	

2.) How many people live in your household? ________

3.) How many sons and daughters are there from household head and spouse? ________

4.) How many children attending school/madrasa or college are there in your household? ________

Problems of the household and general expectations

5.) What are the three main problems your household has to cope with? (Maximum one problem per box)	1.	2.	3.
6.) Would you need help from the government or NGOs to solve this problem?	☐ yes ☐ no	☐ yes ☐ no	☐ yes ☐ no
If yes: 7.) What could the government or NGOs do to help you solve this problem? (Please fill in solutions to respective problems from above)	1.	2.	3.

2

8.) What are the most important things you need to have a happy life and feel well?

a) ______

b) ______

c) ______

9.) Regarding the development of your village, what is missing in your village?

a) ______

b) ______

c) ______

10.) Has the general living condition in your household improved, did it stay the same or degrade within the last three years? (Please read out answers and tick one)

☐ improved, why? ______
☐ stayed the same
☐ degraded, why? ______

Economic situation

	Current Situation	**Before 3 years**
11.) Main occupations of household head (Please tick maximum three most important occupations)	1. farmer / sharecropper 2. agricultural labour 3. manufacturing of agricultural products 4. tending to the cattle/producing fodder 5. seasonal worker 6. craft/skill worker 7. wage labour in hotels / shops 8. industry / factory / mill worker 9. rickshaw / van pulling 10. transport business 11. shopkeeper 12. trader 13. teacher 14. housewife 15. civil servant 16. local political leader 17. UP member / chairman 18. NGO worker 19. student 20. retired 21. other: ______ 22. no occupation	1. farmer / sharecropper 2. agricultural labour 3. manufacturing of agricultural products 4. tending to the cattle/producing fodder 5. seasonal worker 6. craft/skill worker 7. wage labour in hotels / shops 8. industry / factory / mill worker 9. rickshaw / van pulling 10. transport business 11. shopkeeper 12. trader 13. teacher 14. housewife 15. civil servant 16. local political leader 17. UP member / chairman 18. NGO worker 19. student 20. retired 21. other: ______ 22. no occupation

3

	Current Situation	**Before 3 years**
12.) Main occupations of spouse (Please tick maximum three most important occupations)	1. farmer / sharecropper 2. agricultural labour 3. manufacturing of agricultural products 4. tending to the cattle/producing fodder 5. seasonal worker 6. craft/skill worker 7. wage labour in hotels / shops 8. industry / factory / mill worker 9. rickshaw / van pulling 10. transport business 11. shopkeeper 12. trader 13. teacher 14. housewife 15. civil servant 16. local political leader 17. UP member / chairman 18. NGO worker 19. student 20. retired 21. other: ______ 22. no occupation	1. farmer / sharecropper 2. agricultural labour 3. manufacturing of agricultural products 4. tending to the cattle/producing fodder 5. seasonal worker 6. craft/skill worker 7. wage labour in hotels / shops 8. industry / factory / mill worker 9. rickshaw / van pulling 10. transport business 11. shopkeeper 12. trader 13. teacher 14. housewife 15. civil servant 16. local political leader 17. UP member / chairman 18. NGO worker 19. student 20. retired 21. other: ______ 22. no occupation
13.) Overall average monthly expenditures of all household members (Taka/month)		
14.) Average monthly household savings (Taka/month)		
15.) Fixed loans taken by the household to cover bigger investments (e.g. from Grameen, BRAC) (Taka)		
16.) Average monthly loans taken by the household to cover monthly expenditures (e.g. from neighbours) (Taka/month)		
17.) Main Sources of household income in order of importance (as precise as possible, e.g. rice cultivation, fruit trading, sewing)	1. ______ 2. ______ 3. ______	1. ______ 2. ______ 3. ______
18.) Monthly income from respective source (Taka/month) (Please fill in income for respective sources from above)	1. ______ Taka/month 2. ______ Taka/month 3. ______ Taka/month	1. ______ Taka/month 2. ______ Taka/month 3. ______ Taka/month

4

Energy for Cooking

19.) Please complete the following table concerning the energy sources used for cooking and the respective expenditures:

Energy source	Energy source currently used for cooking?	Current monthly expenditures (Taka/month)	Energy source used for cooking three years ago?	Monthly expenditures three years ago (Taka/month)
Wood	☐		☐	
Roots	☐		☐	
Tree leaves	☐		☐	
Crop Residues (e.g. straw, jute stalks)	☐		☐	
Wood dust (bhushi)	☐		☐	
Dung	☐		☐	
Kerosene	☐		☐	
Other energy source (specify): ____________	☐		☐	

20.) What percentage of the firewood is collected and what percentage is bought from the market?

_________% collected _________% bought from the market

21.) What is the current price for one maund of firewood? ______________ Taka per maund

22.) What was the price for one maund of firewood three years ago? ______________ Taka per maund

23.) Who is in charge of collecting the biomass for cooking in your household?
(Please read out answers - Multiple mentions possible)

☐ Women
☐ Men
☐ Children
☐ (No biomass is collected for cooking)

24.) By average, how much time per day is used by these members of your household to collect biomass for cooking?

_______ hours per day

5

Energy for Lighting

25.) Please complete the following table concerning the energy sources used for lighting and the respective expenditures:

Energy source	Energy source currently used for lighting?	Current monthly expenditures (Taka/month)	Energy source used for lighting three years ago?	Monthly expenditures three years ago (Taka/month)
Candles	☐		☐	
Kerosene	☐		☐	
Electricity (including SHS)	☐		☐	
Other energy source (specify): ____________	☐		☐	

26.) What is the current price for one litre of kerosene? ______________ Taka per litre

27.) What was the price for one litre of kerosene three years ago? ______________ Taka per litre

In case kerosene is/was used::
28.) In the past have there been any accidents in your house relating to kerosene use?

☐ yes, please specify: ____
☐ no

Sources of electricity and expenditures

29.) Please complete the following table concerning the electricity sources available in the household and the respective expenditures: (Expenditures include monthly instalments for SHS!)

Electricity source	Electricity source currently used?	Current monthly expenditures (Taka/month)	Electricity source used three years ago?	Monthly expenditures three years ago (Taka/month)
SHS	☐		☐	
Storage battery (e.g. automotive battery)	☐		☐	
Dry-cell batteries	☐		☐	
Generator (Diesel)	☐		☐	
Electricity bought from neighbour	☐		☐	
Other electricity source (specify): ____________	☐		☐	

6

30.) If you had free choice, what would be your preferred source of electricity?
(Please read out answers - tick one)

☐ Grid ☐ SHS ☐ Other source: ____________
☐ Generator (Diesel) ☐ Storage Battery

31.) Why would you choose this source of electricity? ____________

In case of current use of SHS:
32.) When the battery of your SHS has reached the end of its lifespan, what are you going to do with it?
____

33.) From where did you purchase your SHS?
☐ Grameen Shakti ☐ CMES ☐ Rural Services Foundation (RSF)
☐ Proshika ☐ BRAC ☐ Other: ____________

34.) Do you use a financing option to purchase the SHS or did you pay the whole amount of money?
☐ Financing ☐ Paid whole amount

In case of financing:
35.) What was the amount of down payment for the SHS (Taka) ? ____________ Taka

36.) What is the amount of the monthly instalment you have to pay (Taka) ? ____________ Taka

37.) How long is the life of the loan (months)? ____________ months

38.) Do you have problems paying the monthly instalments?
☐ yes ☐ no

39.) In case the monthly instalments had been 10% higher, would you have bought the system anyway?
☐ yes ☐ no

In case of use of storage battery:

	Current situation	Before 3 years
40.) How often did/do you recharge your storage battery per month?		
41.) What were/are the average costs of recharging the battery per month? (Taka/month)		
42.) What were/are the average costs of transport from your household to the charging station per month? (Taka/month)		
43.) How far did/do you have to travel (one way) to recharge the storage battery? (km)		

7

In case electricity is bought from a neighbour:
44.) What is the neighbour's main electricity source?
(Please tick one)
☐ Grid ☐ SHS
☐ Generator (Diesel) ☐ Storage Battery
☐ Other electricity source (specify): ____________

45.) Do you sell electricity to other households in your village?
☐ yes ☐ no

Case yes:
46.) How much money do you earn by selling electricity to other households per month?
____________ Taka per month

In case no SHS is used in the household:
47.) Have you heard of Solar Home Systems before?
☐ Yes ☐ No

48.) Do you know where you could purchase a solar home system?
☐ Yes ☐ No

49.) Are you planning to purchase a solar home system within the next 6 months?
☐ Yes ☐ No

Case no:
50.) What are the reasons for not using a solar home system in your household?
a) ____________
b) ____________
c) ____________

8

General use of electricity

51.) Which of the following electricity consuming activities do the members of your family do in your household?
(Please read out answers - Multiple mentions possible)

☐ Watching TV ☐ Listening to radio
☐ Reading / Studying under lights ☐ Household work under lights or with appliances
☐ Charging of mobile phones ☐ Income generating work under lights (e.g. handicrafts)

☐ Other electricity consuming activities (specify): ____________________

52.) Please complete the following table with the number of electrical devices and hours of daily use in the household:

	Number	Hours of use per day
Tube lights		
LED lights		
B/W TV		
Colour TV		
Radio / Tape Recorder		
Fan		
Mobile charger		
Other:		
Other:		

53.) How often are members of neighbouring families who are not having a source of electricity in their own house come around your home?
(Please read out answers - tick one)

☐ Daily ☐ Several times a week
☐ Once a week ☐ 1 – 3 times per month
☐ Less than once a month ☐ Never

In case of neighbours coming around sometimes:

54.) People from how many non-electrified neighbouring households are visiting your home regularly?

People from ________ households

55.) Which of the following electricity consuming activities do the members of neighbouring families do in your household?
(Please read out answers - Multiple mentions possible)

☐ Watching TV ☐ Listening to radio
☐ Reading / Studying under lights ☐ Income generating work under lights (e.g. handicrafts)
☐ Charging of mobile phones

☐ Other electricity consuming activities (specify): ____________________

Appraisal of electricity and Solar Home System

56.) In your opinion, what are the three most important benefits of electricity from your current source?

a) ____________________
b) ____________________
c) ____________________

57.) In your opinion, what are the three greatest disadvantages of electricity from your current source?

a) ____________________
b) ____________________
c) ____________________

In case of SHS use:

58.) How much are you satisfied with the benefits of your SHS?
(Please tick one)

☐ Very much ☐ More or less ☐ Not at all

59.) Would you recommend a SHS to relatives, friends, neighbours, etc.?

☐ yes ☐ no

60.) Men, Women, Children - who benefits most from the electricity supply from the SHS?
(Multiple mentions possible)

☐ Men ☐ Women
☐ Children ☐ Other (specify): ____________________

61.) Why? ____________________

62.) What could be improved about the SHS?

____
____

Productive activities in the household

	Current Situation	Before 3 years
63.) Was/is there any income generating business or production going on in your household?	☐ yes ☐ no	☐ yes ☐ no

In case business/production existed/exists:

	Current Situation	Before 3 years
64.) What kind of income generating business / production was/is there in your household? (Please tick one most important production / business)	☐ husking rice (*Dheki*) ☐ preparing puff rice / cakes (*Muri/pitha*) ☐ sewing cloths ☐ making handicrafts ☐ carpenter's workshop ☐ other, specify: ______	☐ husking rice (*Dheki*) ☐ preparing puff rice / cakes (*Muri/pitha*) ☐ sewing cloths ☐ making handicrafts ☐ carpenter's workshop ☐ other, specify: ______
65.) Average income through business/ production per month (Taka)		

66.) Do you use electricity for lighting of your business/productive purposes in the household?
☐ yes ☐ no

67.) Do you use electricity for electric appliances or machinery for your business/productive purposes in the household?
☐ yes, specify appliances/machinery: ______
☐ no

Case lighting or machinery for business/production is used and SHS existent:
68.) What advantages of electricity do you experience for your business or productive activities?
a) ______
b) ______
c) ______

69.) Did the use of lighting or machinery increase your monthly production or number of customers?
☐ yes, quantify the increase: before:______ / after:______
☐ no

70.) Did the use of lighting or machinery increase your monthly income from business/production?
☐ yes, quantify the increase: before:______Taka / after:______Taka
☐ no

11

Social life

71.) How much do you agree with the following statements?
(Please read out answers and tick one answer respectively)

a) "In my house it is easy to read in the evening"
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

b) "It is easy for my family to get news and information"
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

c) "I feel safe in my household in the evening"
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

d) "We often socialize with friends, relatives or neighbours at our home in the evening"
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

In case of SHS use:
72.) What changes in daily life could be observed after installing the SHS in your household?
a) ______
b) ______
c) ______

73.) Did the installation of the SHS reduce the daily workload for women in the family?
☐ yes ☐ no

Case yes:
74.) How? ______

75.) Did the installation of the SHS reduce the daily workload for men in the family?
☐ yes ☐ no

Case yes:
76.) How? ______

77.) When did the adult members of your family go to bed before you got your solar home system?
______ PM

78.) When do the adult members of your family currently go to bed in the evening? ______ PM

12

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

	Current situation (hours/day)	Before 3 years (hours/day)
Women		
Men		
Children		

80.) Please complete the tables regarding the average time spent on the following activities after sunset for household head, spouse and children of the household:
(read out all activities and fill in respective number of hours)

a) Household Head

	Current situation (hours/evening)	Before 3 years (hours/evening)
Household work		
Productive Work (e.g. sewing) / Business		
Going to the bazaar / Shopping		
Socialising with friends / relatives / neighbours		
Watching TV		
Listening to radio		
Reading / Studying		
Playing		
Other, specify:		

b) Spouse

	Current situation (hours/evening)	Before 3 years (hours/evening)
Household work		
Productive Work (e.g. sewing) / Business		
Going to the bazaar / Shopping		
Socialising with friends / relatives / neighbours		
Watching TV		
Listening to radio		
Reading / Studying		
Playing		
Other, specify:		

13

c) Children

	Current situation (hours/evening)	Before 3 years (hours/evening)
Household work		
Productive Work (e.g. sewing) / Business		
Going to the bazaar / Shopping		
Socialising with friends / relatives / neighbours Watching TV		
Listening to radio		
Reading / Studying		
Playing		
Other, specify:		

In case of TV use:
81.) For which purposes do you mainly use the TV?
(Please read out answers - Multiple mentions possible)
- ☐ Entertainment (music, movies, etc.)
- ☐ Information on current events (news, political discussions, etc.)
- ☐ Information on agriculture (agricultural programmes)
- ☐ Education (educational programmes)
- ☐ Other (specifiy): ____

82.) What are the three biggest benefits of owning a TV?

a) ____

b) ____

c) ____

83.) In your family have there been any negative developments after introducing the TV?

- ☐ yes, please specify: ____
- ☐ no

14

In case of radio use:

84.) For which purpose do you mainly use the radio?
(Please read out answers - Multiple mentions possible)

☐ Entertainment (music, radio play, etc.)
☐ Information on current events (news, political discussions, etc.)
☐ Information on agriculture (agricultural programmes)
☐ Education (educational programmes)

☐ Other (specifiy): ____________________

85.) What are the three biggest benefits of owning a radio?

a) ____________________

b) ____________________

c) ____________________

86.) In your family have there been any negative developments after introducing the radio? Please specify!

☐ yes, please specify: ____________________
☐ no

87.) Do members of your household suffer from the following medical conditions?
(Please read out answers - Multiple mentions possible)

☐ Eye irritations ☐ Nose irritation ☐ None of these
☐ Throat irritation ☐ Difficulties in breathing

88.) Is some member of your household planning to move away from the village within the next 12 months?

☐ Yes ☐ No

Case yes:

89.) Which member of your family? ____________________

90.) Where does this person want to move?
(Please tick one)

☐ Dhaka ☐ Chittagong
☐ Khulna ☐ Other large town, specify: ____________
☐ Small town, specify: ____________
☐ Another village

91.) What is the main reason for migrating?
(Please tick one)

☐ Marriage ☐ Education
☐ Looking for work ☐ Other reason, specify: ____________

Remarks:

____

A6 Household survey – questionnaire type 2

Questionnaire on socio-economic impacts of rural SHS electrification

gtz universität mainz

Household Type 2 – Household with
☐ **no electricity (except dry-cell batteries, e.g. in torches, radios etc.)**

Basic Data Questionnaire

Interviewer:

Name	
Sex	☐ male ☐ female

No. of questionnaire	
Date	
Village	
Name of Family	

Village Type:
(Please tick one)
☐ Village with SHS disseminated
☐ Village without SHS disseminated

Main Interviewee:
(Please tick one)
☐ head
☐ spouse
☐ (other household member: name: ____________
age: ____________
relation to household head: ____________)

1

Households Structure

1.) Please complete the following table for household head and spouse:

	Name	Sex	Age (years)	Marital status (Please tick one)	How many years of schooling completed? (Enter the years, 0 no schooling)
Household Head		☐ male ☐ female		☐ Single ☐ Married ☐ Divorced ☐ Widowed	
Spouse		☐ male ☐ female		☐ Single ☐ Married ☐ Divorced ☐ Widowed	

2.) How many people live in your household? ________

3.) How many sons and daughters are there from household head and spouse? ________

4.) How many children attending school/madrasa or college are there in your household? ________

Problems of the household and general expectations

5.) What are the three main problems your household has to cope with? (Maximum one problem per box)	1.	2.	3.
6.) Would you need help from the government or NGOs to solve this problem?	☐ yes ☐ no	☐ yes ☐ no	☐ yes ☐ no
If yes: **7.) What could the government or NGOs do to help you solve this problem?** (Please fill in solutions to respective problems from above)	1.	2.	3.

2

8.) What are the most important things you need to have a happy life and feel well?

a) ____________________

b) ____________________

c) ____________________

9.) Regarding the development of your village, what is missing in your village?

a) ____________________

b) ____________________

c) ____________________

10.) Has the general living condition in your household improved, did it stay the same or degrade within the last three years? (Please read out answers and tick one)

☐ improved, why? ____________________

☐ stayed the same

☐ degraded, why? ____________________

Economic situation

	Current Situation	Before 3 years
11.) Main occupations of household head (Please tick maximum three most important occupations)	1. farmer / sharecropper 2. agricultural labour 3. manufacturing of agricultural products 4. tending to the cattle/producing fodder 5. seasonal worker 6. craft/skill worker 7. wage labour in hotels / shops 8. industry / factory / mill worker 9. rickshaw / van pulling 10. transport business 11. shopkeeper 12. trader 13. teacher 14. housewife 15. civil servant 16. local political leader 17. UP member / chairman 18. NGO worker 19. student 20. retired 21. other: __________ 22. no occupation	1. farmer / sharecropper 2. agricultural labour 3. manufacturing of agricultural products 4. tending to the cattle/producing fodder 5. seasonal worker 6. craft/skill worker 7. wage labour in hotels / shops 8. industry / factory / mill worker 9. rickshaw / van pulling 10. transport business 11. shopkeeper 12. trader 13. teacher 14. housewife 15. civil servant 16. local political leader 17. UP member / chairman 18. NGO worker 19. student 20. retired 21. other: __________ 22. no occupation

3

	Current Situation	Before 3 years
12.) Main occupations of spouse (Please tick maximum three most important occupations)	1. farmer / sharecropper 2. agricultural labour 3. manufacturing of agricultural products 4. tending to the cattle/producing fodder 5. seasonal worker 6. craft/skill worker 7. wage labour in hotels / shops 8. industry / factory / mill worker 9. rickshaw / van pulling 10. transport business 11. shopkeeper 12. trader 13. teacher 14. housewife 15. civil servant 16. local political leader 17. UP member / chairman 18. NGO worker 19. student 20. retired 21. other: __________ 22. no occupation	1. farmer / sharecropper 2. agricultural labour 3. manufacturing of agricultural products 4. tending to the cattle/producing fodder 5. seasonal worker 6. craft/skill worker 7. wage labour in hotels / shops 8. industry / factory / mill worker 9. rickshaw / van pulling 10. transport business 11. shopkeeper 12. trader 13. teacher 14. housewife 15. civil servant 16. local political leader 17. UP member / chairman 18. NGO worker 19. student 20. retired 21. other: __________ 22. no occupation
13.) Overall average monthly expenditures of all household members (Taka/month)		
14.) Average monthly household savings (Taka/month)		
15.) Fixed loans taken by the household to cover bigger investments (e.g. from Grameen, BRAC) (Taka)		
16.) Average monthly loans taken by the household to cover monthly expenditures (e.g. from neighbours) (Taka/month)		
17.) Main Sources of household income in order of importance (as precise as possible, e.g. rice cultivation, fruit trading, sewing)	1. __________ 2. __________ 3. __________	1. __________ 2. __________ 3. __________
18.) Monthly income from respective source (Taka/month) (Please fill in income for respective sources from above)	1. __________ Taka/month 2. __________ Taka/month 3. __________ Taka/month	1. __________ Taka/month 2. __________ Taka/month 3. __________ Taka/month

4

Energy for Cooking

19.) Please complete the following table concerning the energy sources used for <u>cooking</u> and the respective expenditures:

Energy source	Energy source currently used for cooking?	Current monthly expenditures (Taka/month)	Energy source used for cooking three years ago?	Monthly expenditures three years ago (Taka/month)
Wood	☐		☐	
Roots	☐		☐	
Tree leaves	☐		☐	
Crop Residues (e.g. straw, jute stalks)	☐		☐	
Wood dust (bhushi)	☐		☐	
Dung	☐		☐	
Kerosene	☐		☐	
Other energy source (specify): ________	☐		☐	

20.) What percentage of the firewood is collected and what percentage is bought from the market?

_________% collected _________% bought from the market

21.) What is the current price for one maund of firewood? ______________ Taka per maund

22.) What was the price for one maund of firewood three years ago? ______________ Taka per maund

23.) Who is in charge of collecting the biomass for cooking in your household?
(Please read out answers - Multiple mentions possible)
☐ Women
☐ Men
☐ Children
☐ (No biomass is collected for cooking)

24.) By average, how much time per day is used by these members of your household to collect biomass for cooking?

_______ hours per day

5

Energy for Lighting

25.) Please complete the following table concerning the energy sources used for <u>lighting</u> and the respective expenditures:

Energy source	Energy source currently used for lighting?	Current monthly expenditures (Taka/month)	Energy source used for lighting three years ago?	Monthly expenditures three years ago (Taka/month)
Candles	☐		☐	
Kerosene	☐		☐	
Electricity	☐		☐	
Other energy source (specify): ________	☐		☐	

26.) What is the current price for one litre of kerosene? ______________ Taka per litre

27.) What was the price for one litre of kerosene three years ago? ______________ Taka per litre

In case kerosene is/was used::
28.) In the past have there been any accidents in your house relating to kerosene use?
☐ yes, please specify: ____________________
☐ no

General use of electricity

29.) How often are members of your family visiting neighbours that have electricity in their household?
(Please read out answers - tick one)
☐ Daily ☐ Several times a week
☐ Once a week ☐ 1 – 3 times per month
☐ Less than once a month ☐ Never / No neighbours with electricity existent

In case of visiting neighbours with electricity sometimes:
30.) Which of the following activities do you usually do when visiting the neighbours with electricity?
(Please read out answers - Multiple mentions possible)
☐ Watching TV ☐ Listening to radio
☐ Reading / Studying under lights ☐ Income generating work under lights (e.g. handicrafts)
☐ Charging of mobile phone

☐ Other electricity consuming activities (specify): ____________________

6

Appraisal of electricity and Solar Home System

31.) In your opinion, what are the three most important benefits of electricity?

a) ______

b) ______

c) ______

32.) In your opinion, what are the three greatest disadvantages of electricity?

a) ______

b) ______

c) ______

33.) Do you wish to have electricity in your household?

☐ yes ☐ no

Case yes:

34.) What would you use it for?

a) ______

b) ______

c) ______

35.) What would be your preferred source of electricity? (Please read out answers - tick one)

☐ Grid ☐ SHS ☐ Other source: ______

☐ Generator (Diesel) ☐ Storage Battery

36.) Why would you choose this source of electricity? ______

37.) Have you heard of Solar Home Systems before?

☐ Yes ☐ No

38.) Do you know where you could purchase a solar home system?

☐ Yes ☐ No

39.) Are you planning to purchase a solar home system within the next 6 months?

☐ Yes ☐ No

Case no:

40.) What are the reasons for not using a solar home system in your household?

a) ______

b) ______

c) ______

7

41.) How much could you afford to pay for electricity per month (Taka)? ______ Taka per month

42.) Imagine a small SHS making decent lighting possible. TV or radios could not be used with this system. Would you be interested in purchasing such a system if you could afford it?

☐ Yes ☐ No

Case yes:

43.) Could you afford monthly instalments of (insert a-e) to purchase the system?

Stop questioning as soon as "yes" occurs.

a) 500 Taka

☐ Yes ☐ No

b) 400 Taka

☐ Yes ☐ No

c) 300 Taka

☐ Yes ☐ No

d) 200 Taka

☐ Yes ☐ No

e) 100 Taka

☐ Yes ☐ No

Productive activities in the household

	Current Situation	Before 3 years
44.) Was/Is there any income generating business or production going on in your household?	☐ yes ☐ no	☐ yes ☐ no

In case business/production existed/exists:

	Current Situation	Before 3 years
45.) What kind of income generating business / production was/is there in your household? (Please tick one most important production / business)	☐ husking rice (*Dheki*) ☐ preparing puff rice / cakes (*Muri/pitha*) ☐ sewing cloths ☐ making handicrafts ☐ carpenter's workshop ☐ other, specify: ______	☐ husking rice (*Dheki*) ☐ preparing puff rice / cakes (*Muri/pitha*) ☐ sewing cloths ☐ making handicrafts ☐ carpenter's workshop ☐ other, specify: ______
46.) Average income through business/ production per month (Taka)		

8

Social life

47.) How much do you agree with the following statements?
(Please read out answers and tick one answer respectively)

a) "In my house it is easy to read in the evening"
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

b) "It is easy for my family to get news and information"
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

c) "I feel safe in my household in the evening"
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

d) "We often socialize with friends, relatives or neighbours at our home in the evening"
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

48.) When do the adult members of your family currently go to bed in the evening? _______ PM

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

	Current situation (hours/day)	Before 3 years (hours/day)
Women		
Men		
Children		

50.) Please complete the tables regarding the average time spent on the following activities after sunset for household head, spouse and children of the household:
(read out all activities and fill in respective number of hours)

a) Household Head

	Current situation (hours/evening)	Before 3 years (hours/evening)
Household work		
Productive Work (e.g. sewing) / Business		
Going to the bazaar / Shopping		
Socialising with friends / relatives / neighbours		
Watching TV		
Listening to radio		
Reading / Studying		
Playing		
Other, specify:		

9

b) Spouse

	Current situation (hours/evening)	Before 3 years (hours/evening)
Household work		
Productive Work (e.g. sewing) / Business		
Going to the bazaar / Shopping		
Socialising with friends / relatives / neighbours		
Watching TV		
Listening to radio		
Reading / Studying		
Playing		
Other, specify:		

c) Children

	Current situation (hours/evening)	Before 3 years (hours/evening)
Household work		
Productive Work (e.g. sewing) / Business		
Going to the bazaar / Shopping		
Socialising with friends / relatives / neighbours		
Watching TV		
Listening to radio		
Reading / Studying		
Playing		
Other, specify:		

10

51.) Do members of your household suffer from the following medical conditions?
(Please read out answers - Multiple mentions possible)

☐ Eye irritations ☐ Nose irritation ☐ None of these
☐ Throat irritation ☐ Difficulties in breathing

52.) Is some member of your household planning to move away from the village within the next 12 months?

☐ Yes ☐ No

Case yes:

53.) Which member of your family? ____________________

54.) Where does this person want to move?
(Please tick one)

☐ Dhaka ☐ Chittagong
☐ Khulna ☐ Other large town, specify: ____________
☐ Small town, specify: ____________
☐ Another village

55.) What is the main reason for migrating?
(Please tick one)

☐ Marriage ☐ Education
☐ Looking for work ☐ Other reason, specify: ____________________

Remarks:

A7 Guideline questions for interviews with shops/businesses

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- Interviews with shop keepers with SHS electricity -

Village:	
Name of interviewee: **Business:**	
Date & Time:	
Place:	
Duration:	

Products on sale / Services offered: ______________________________

Electricity through
☐ Own System ☐ Micro Utility

Monthly Expenditures for electricity (instalments) : __________ Taka

Current shop income per month: __________ Taka

Shop Income per month before 3 years: __________ Taka

Use of electricity:
☐ Lighting
☐ TV
☐ Radio
☐ Other: __________________

Why did you decide to purchase the solar system?

What are the advantages of the Solar System for your business?

After installing the Solar PV did you experience old customers spending more money at your shop?
☐ Yes ☐ No

After installing the Solar PV did you experience new customers coming to your shop?
☐ Yes ☐ No

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- Interviews with shop keepers not having SHS electricity -

Village:	
Name of interviewee: **Business:**	
Date & Time:	
Place:	
Duration:	

Products on sale / Services offered: ______________________________

What is the main source of lighting in your shop?
☐ Kupi
☐ Hurricane
☐ Other: __________________

Monthly Expenditures for lighting (e.g. kerosene): __________ Taka

Current shop income per month: __________ Taka

Shop income per month before 3 years: __________ Taka

Since the introduction of Solar Systems in some of the shops of your village did you experience any impact on your business activities?
☐ Yes ☐ No

Case yes: what kind of impacts?

After the Solar PVs were installed in other shops of your village did you experience old customers coming less frequent to your shop preferring the shops with electricity?
☐ Yes ☐ No

Would you like to have electricity in your shop?
☐ Yes
☐ No

Case yes: why? ____

I

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