Productive Uses of Photovoltaic Technology in Rural Bangladesh - Potentials, Barriers, Recommendations

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List of Abbreviations

BARI	Bangladesh Agricultural Research Institute
Bbl	Barrel
BDS	Business Development Services
BDT	Bangladeshi Taka
BMDA	Barind Multipurpose Development Authority
BRAC	Bangladesh Rural Advancement Committee
BUET	Bangladesh University of Engineering and Technology (BUET)
CFL	Compact Fluorescent Lamp
CMES	Centre for Mass Education in Science
CO_2	Carbon Dioxide
DC	Direct Current
ESMAP	Energy Sector Management Assistance Program
FAO	Food and Agriculture Organization of the United Nations
ft	feet
GDP	Gross Domestic Product
GEF	Global Environment Facility
GOB	Government of Bangladesh
GS	Grameen Shakti
GTZ	Gesellschaft für Technische Zusammenarbeit
ha	hectar
HELP	Home Employment Lighting Programme
HLF	Himalayan Light Foundation
H.P.	Horse Power
HSD	High Speed Diesel Oil
IDA	International Development Association
IDCOL	Infrastructure Development Company Limited
KfW	Kreditanstalt für Wiederaufbau
kg	Kilogramme
kWh	Kilowatt-hour
kWp	Kilowatt-peak
LGED	Local Government Engineering Department
MNES	Ministry of Non-conventional Energy Sources (MNES)
NGO	Non-governmental Organization
PKSF	Palli Karma-Sahayak Foundation
PO	Partner Organization
PV	Photovoltaic
RE	Renewable Energy
REB	Rural Electrification Board

RERC	Renewable Energy Research Centre
REREDP	Rural Electrification and Renewable Energy Development Project
RET	Renewable Energy Technology
RSF	Rural Services Foundation
SELCO	Solar Electric Light Company
SHS	Solar Home System
SME	Small and Medium Enterprises
SRE	Sustainable Rural Energy
SSHS	Small Solar Home System
t	metric ton
TV	Television
UNDP	United Nations Development Programme
W	Watt
Wh	Watt-hour
Wp	Watt-peak

Executive Summary

Positive economic impacts of rural electrification programs in developing countries are mainly due to the productive or income-generating use of electricity. In rural Bangladesh, photovoltaic (PV) technology in the form of stand-alone Solar Home Systems (SHS) has been widely applied for rural electrification purposes. However, apart from notable positive social benefits, economic impacts have proven to be rather limited, mainly due to widespread lack of productive uses of the SHS technology (BLUNCK 2007). This study aimed at identifying the potentials and barriers for productive uses of SHS as well as other PV applications in rural Bangladesh. It further aimed at providing recommendations for future interventions of the government, donors, NGOs and the private sector to support such productive applications. The study followed a qualitative approach including literature review, interviews with relevant stakeholders and several field visits.

Productive uses of electricity should be promoted as they can maximize the economic and social benefits of energy access, facilitate the achievements of the Millennium Development Goals and contribute to economic sustainability of rural electrification projects. The main areas of intervention to promote productive applications of electricity are the introduction of productive technologies, micro credit and Business Development Services (BDS). Furthermore, improved infrastructure and access to markets can be provided. International experience with productive applications of solar PV systems has so far been mixed. The technical application potential of solar technology is broad, with many electrification projects worldwide reporting productive uses in agriculture as well as in cottage industries and commercial businesses. While solar PV seems appropriate for household lighting and applications that use small amounts of electricity, it may not be suitable for promoting productive applications on a large-scale (e.g. machines for industrial manufacturing processes), largely because of the high costs of delivered electricity involved. Still, the small-scale productive application of small loads from solar PV systems seem to be potential carriers of rural socio-economic development.

Quantitative information on the extent of productive activities or income generation facilitated by SHS in general and Bangladesh in particular is hardly available. Prominent examples of programs promoting productive uses of SHS include the introduction of electric sewing machines in India through SELCO and the Home Employment Lighting Programme (HELP) in Nepal. In Bangladesh, the main productive applications of SHS include the lighting of existing small cottage industries in SHS households as well as lighting and TV in rural market shops and small businesses to extend opening and production hours and improve customer attraction. In some cases new mobile charging businesses have developed. In the agricultural sector, SHS are used for lighting of poultry farms (increased productivity) and fish ponds (increased safety). There is still some potential for further increasing the amount of SHS-facilitated domestic income generation and the use of SHS in small businesses. To do so, close cooperation with local stakeholders in the area of SME/cottage industries promotion (e.g. PKSF) is recommended. Additional specific incentives through IDCOL might be effective to create more initiative among POs to actively promote SHS among rural businesses. Increased cooperation with national and local poultry associations might result in higher awareness and demand for SHS in respective businesses. As small SHS below 30 Wp have proven to be used more frequently for income generating purposes (mainly for lighting of small shops) their market-based dissemination should be particularly supported. Apart from small soldering irons for niche markets, there are currently no cost-effective productive appliances available for the SHS. In all observed cases, investment costs were significantly higher than any economic benefit gained by the use of the respective appliances.

Besides the use of SHS, the application of PV technology for water pumping has been discussed in Bangladesh for several years. Despite the number of more than 50,000 PV pumps in use worldwide and existing practical experience from India, initiatives to promote this technology in Bangladesh have so far been rare. Existing initiatives and pilot projects were limited to technical demonstrations, but did not focus on developing sustainable economic and social dissemination models. ISLAM (2006) identified the replacement of about 1.15 million units of small (4 H.P.) diesel low lift pumps as the potential target market for PV surface irrigation in Bangladesh. Most potential stakeholders in the dissemination of the PV irrigation technology are confident that PV pumping should be the next large-scale PV application in Bangladesh. The most significant barriers for wide scale dissemination of PV irrigation systems are the high

initial investment costs, the lack of field experience regarding effective financing and management systems and the limited use of water-saving irrigation techniques throughout the country. To overcome these barriers, more research and pilot projects on economically and socially sustainable PV irrigation systems including water-conserving irrigation techniques have to be initiated. For large-scale dissemination, financing schemes including grants and soft loans could be developed and introduced by the Infrastructure Development Company Limited (IDCOL) and its partners in a second stage.

Other potential productive applications of PV technology include solar aeration of aquacultures and the use of electricity from PV mini grids for productive appliances and small machinery. However at this time, the introduction of PV-powered aeration systems for aquacultures in Bangladesh does not seem to be reasonable as for the very small number of existing aeration systems the need for aeration is very infrequent. For existing traditional extensive pond cultivation an effect on productivity through the introduction of aeration systems is not expected. In case of an increase of intensive and highly-intensive aquacultures (shrimp farms with large amounts of supplemental feeding and fertilization) within the next years, the promotion of PV-powered aeration systems could be reconsidered. Previous experience with PV mini grids is so far almost non-existent in Bangladesh. However, given the larger amount of electric loads provided in a PV mini grid the potentials for productive uses through productive appliances and small machinery are very likely to be much higher compared to a stand alone SHS. It depends on further field level experience from pilot schemes whether further involvement of the GOB or donors in the area of PV mini grids might prove reasonable. At this time, financing and technical support for individual pilot initiatives is recommended.

1 Introduction

The productive or income-generating use of electric energy is a precondition for most of the positive economic impacts related to rural electrification programs in developing countries. In rural Bangladesh, photovoltaic (PV) technology has been widely in use for rural electrification purposes, mainly in the form of stand-alone Solar Home Systems (SHS). However, besides significant positive social benefits, economic impacts have proven to be rather limited, mainly due to widespread non-existence of productive applications of the SHS technology (BLUNCK 2007). This study aims at identifying the potentials and barriers for productive uses of SHS as well as other PV applications in rural Bangladesh. It further provides recommendations for future interventions of the government, donors, NGOs and the private sector to support such productive applications. The study followed a qualitative approach including a literature review, interviews with experts as well as several field visits.

1.1 Background

The main application of PV technology in rural Bangladesh is the SHS. The use of SHS for rural off-grid electrification has become very popular during the last years. Following the initial experience from a French-funded pilot project in Narsingdi implemented by the Rural Electrification Board (REB) in 1997, several initiatives for the large-scale promotion of the SHS technology were launched. Through REB's follow-up projects 'Diffusion of Renewable Energy Technologies' and 'Rural Electrification through Solar Energy' (IDA credit no. 3679BD) about 13,000 SHS were disseminated using the 'fee for service' model.

Encouraged by the success of the REB pilot project in Narsingdi, NGOs soon went ahead with their own SHS dissemination programs. First commercial activities with SHSs were initiated by Grameen Shakti (GS) in 1997 following 'cash sale' and 'credit sale' approaches. A new phase of SHS promotion started in 2002 with the implementation of the 'Rural Electrification and Renewable Energy Development Project' (REREDP), which is jointly financed by the International Development Association (IDA), Global Environment Facility (GEF), German KfW and GTZ over 2002 to 2009. The Infrastructure Development Company Limited (IDCOL) – a government-owned entity – disseminates SHSs through 15 partner organizations (POs), namely experienced NGOs such as GS or the Bangladesh Rural Advancement Committee (BRAC) (together disseminating about 80% 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. 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. 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. 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 240,000 SHSs sold by October 2008, the IDCOL program is one of the fastest growing renewable energy programs in the world.

A recent study conducted by the author in 2007 revealed detailed information about the development impact of the SHS dissemination in rural areas. Social and environmental impacts where found to be significant: due to electric lighting, working conditions in households and businesses as well as conditions for studying of children were improved. Villagers with electric lights felt in general much safer than their counterparts in households without electricity. Avoidance of kerosene contributed positively to the overall health situation of rural households and the access to information was significantly improved through the use of TVs and radios. Furthermore, solar chargers for mobile phones provided facilities for telecommunication. The use of SHS reduced kerosene consumption and therewith CO_2 emissions (BLUNCK 2007: 121).

When it comes to economic impacts of the SHS, results were less euphoric. While some shops and businesses used SHS for extending working hours and improving customer attraction, SHS were hardly ever used to support income-generating activities on household level

(BLUNCK 2007). As most of the systems are used on household level the overall economic impact from SHS dissemination programs in Bangladesh seems to be rather small.

Other widespread productive applications of PV technology are so far non-existent in the context of rural Bangladesh. The focus of donor interventions has up to now mainly concentrated on the market-based promotion of SHS, whereas the large-scale promotion of other productive or non-productive applications of solar PV have not been targeted by either the Government of Bangladesh (GOB) or donor initiatives.

1.2 Objective

This study aims at providing an overview on the **potentials** for productive use of SHS as well as other PV applications in rural Bangladesh. What are the major productive uses that are already taking place and what other applications might be thinkable? What are the experiences of organizations and individuals involved in the promotion of PV technology? The study further identifies existing **barriers** for the widespread use of PV technology for income generation in Bangladesh. What are the factors hampering the large-scale application of electricity from PV for income generation? From these findings the study derives **recommendations** for decision makers to initiate effective interventions for promoting productive PV applications.

1.3 Approach and Study Outline

As it was the aim of this study to provide a first basic and broad overview on existing potentials for the productive use of solar PV, this study followed a qualitative methodology. As a first step of data collection, a review on existing literature regarding productive uses of solar PV was conducted. Ten guided interviews with representatives from organizations involved in the promotion of PV technology as well as individual experts were conducted between September 7 and 24, 2008. Guideline questions (see Annex A2) were used to provide a comparable basic set of information for all the interviews. The guideline questions often led to more in-depth discussions on certain aspects that were most relevant for the respective interviewees. After the identification of the most important potential productive applications of solar PV technology, additional short interviews with experts from the fishery and shrimp farming sectors were conducted. For an overview on all interviewees please refer to Annex A1. One field trip organized with the support of IDCOL to Mymensingh district (September 21-22, 2008) revealed more information on ongoing productive uses of SHS, while another field trip to a fishery of the IFAD Agro complex in Bahuli/Bhaluka near Mymensingh provided an overview on application potentials of solar PV in the fishery sector.

Chapter 2 provides an overview on issues regarding the productive use of electricity in general as well as productive use of solar PV in particular. It presents a working definition of “productive use of electricity”, elaborates on the need for promotion of productive uses and summarizes international experiences on productive uses of solar PV technology in developing countries. **Chapter 3** focuses on the potential, barriers and recommendations for productive uses of the most common PV application in Bangladesh: the SHS. In **chapter 4**, the potential application of PV technology for irrigation purposes and drinking water supply in rural areas is discussed. **Chapter 5** gives an overview on two other potential productive applications of solar PV in Bangladesh, namely pond aeration and small industries in PV mini grids. In **chapter 6**, the main conclusions and recommendations from the preceding chapters will be summarized.

2 Productive Use of PV technology

Productive use of electricity is the basis for positive economic impacts of rural electrification programs. The following paragraphs will focus on a working definition of the term ‘productive use’, explore the reasoning for the promotion of productive uses through governments or donor agencies and give an overview on potential interventions to support productive uses. Paragraph 2.4 will provide an overview on common productive applications of solar PV in developing countries.

2.1 Productive Use of Electricity – A Working Definition

Before exploring the potentials of productive use of solar electricity the term ‘productive use of electricity’ must be clearly defined. In the general discussion there have been several attempts to come up with a clear definition. While in some cases productive use is mainly defined through income generating activities that are directly positively affected by the use of electricity, others draw a much broader definition by including the use of electric energy for education and health or other welfare related activities.

A World Bank paper by Kamal KAPADIA (2004: 3) defines productive uses of energy as activities “that involve the utilization of energy – both electric, and non-electric energy in the forms of heat, or mechanical energy - for activities that enhance income and welfare. These activities are typically in the sectors of agriculture, rural enterprise, health and education. Examples of such activities are pumping water for agriculture, agro-processing, lighting, information and communications, and vaccine refrigeration”.

In a publication by Jose ETCHEVERRY (2003: 1) the term productive use is defined as referring “broadly to projects that aim at enhancing income generation opportunities and productivity in rural areas (e.g. small industry, agriculture, commercial activities, telecommunications, education and health facilities, clean water, refrigeration, etc.), to improve quality of life and increase local resilience and self-reliance”.

The working definition that will be used for the purpose of this study is following the approach of Ron WHITE’s paper on the GEF-FAO Workshop on Productive Uses of Renewable Energy (2003: 33). ***A productive use of energy is defined as “one that involves the application of energy derived mainly from renewable resources to create goods and/or services either directly or indirectly for the production of income or value. The production of income or value is understood to be achieved by selling products or services at greater than their cost of production, resulting in an increase in the net income of the enterprise or the entrepreneur”.***

The last definition is narrower as it does not allow for interpretation regarding the productive character of activities such as education or health. However, indirect impacts of rural electrification on economic development through ways of improving education and health of rural populations shall not be taken into question; they shall just not be the centre of this particular study. This study focuses mainly on direct economic impacts which might occur through a directly-linked increase in income facilitated by the use of electric energy.

2.2 Why Support Productive Use of Electricity?

In a 1995 review of the World Bank’s rural electrification projects in Asia, the Bank’s Operations Evaluation Department concluded that the “economic returns of rural electrification projects have been considerably lower than expected and a wide range of expected indirect and external benefits have not materialized” (World Bank 1995). One reason for this fact is that most rural electrification initiatives in the past have mainly focused on household and community needs for lighting. Placing rural electrification as part of a broader development approach, however, entails allocating a much higher priority on strategies for using energy for productive uses (ETCHEVERRY 2003: 6).

The GEF-FAO Workshop on Productive Uses of Renewable Energy in 2002 therefore recommended going beyond home lighting applications: “Many rural renewable energy development projects have primarily focused on household lighting using solar home systems (SHS). While such systems provide important social benefits and also may facilitate homebased income generating activities, there are a wide variety of productive-use benefits that can only be captured through applications other than home lighting. These other applications have been neglected in historical development practice” (MARTINOT 2002).

A recent paper by ESMAP (2008: 2) argues that the most efficient way to deliver effective and lasting impacts when designing a rural electrification scheme is to ensure that such programs provide a direct impact on livelihoods and revenue generation, in addition to the more conventional impacts on standards of living. Increasing revenue generation can be accomplished by improving productivity of an existing production process and by creating new lines of activities that will generate employment and local demand.

The main reasons for demanding increased promotion of productive uses in energy projects are (KAPADIA 2004: 4):

- Productive use can **maximize the economic and social benefits of energy access**. Energy projects with productive use components are more likely to lead to rural economic development than projects that simply focus on the provision of electricity, or other forms of energy.
- Energy that is used productively can **facilitate the achievements of the Millennium Development Goals**. Incorporating a ‘productive use’ focus into energy projects makes them more likely to help achieve the Millennium Development Goals.
- Rural electrification projects with a productive use component are more likely to achieve **economic sustainability**. This is for two distinct reasons:
  - Obtaining financing for Renewable Energy Technologies (RET) may be easier as rural financing agencies might be more willing to provide lending to households that use the provided energy to increase their income.
  - As people’s incomes rise through the productive use of energy, their demand for energy services is likely to rise too. This creates attractive market conditions for RET dealers and vendors.

2.3 How to Support Productive Use of Electricity?

Experience from past rural electrification programs has shown that the provision of electricity alone does not necessarily lead to its productive application. There are several reasons why electricity may not be used for productive purposes or small business development. FISHBEIN (2003) summarizes the most important preconditions for productive applications of electric energy in developing countries:

- **Knowledge and skill** by small and micro-business, households and farmers on how to use new-found electrical and motive power for profitable enterprise.
- **Technical and financial management capacity** of small and micro-business, households and farmers, including availability of credit and micro-credit to finance productive tools and equipment.
- A **policy and institutional environment** conducive to business development, willingness to promote decentralized services, etc.
- **Access to markets** for additional or new products produced or services offered as a result of new electrical, heat or motive power
- Availability of a minimum of other complementary **infrastructure services**, such as transport, water supply and ICT services.

Where one or several of these factors are nonexistent, productive use of electricity may be hampered significantly. Programs promoting the productive application of electricity are concentrating on providing the preconditions mentioned above by implementing activities such as providing

- productive technologies,
- micro credit,
- Business Development Services (BDS) and training,
- infrastructure, or

- improved market access (ALLERDICE/ROGERS 2000, VEIT 2006).

Previous experience has shown that activities to promote productive use necessarily seem to involve non-energy sector agencies or organizations to implement respective business development, financing and infrastructure services (KAPADIA 2004).

2.4 Solar PV and Productive Use

Precise information about the installed capacity, or the number of renewable energy systems, used for productive uses in rural areas of less industrialized nations is not readily available; furthermore, published data regarding these figures are scarce. This lack of precise information is particularly notorious in relation to off-farm productive activities (e.g. cottage activities and commercial services). Most of the existing information is anecdotal in nature and provides only a glimpse of the current and potential renewable energy applications (ETCHEVERRY 2003).

An FAO study from 2000 (VAN CAMPEN et al) provides a good qualitative overview on potential productive uses and system set-ups of PV in different countries. Even though pointing out that electric lighting is by far the most common application of PV systems, the study provides a large amount of other income-generating applications in the areas of agriculture, cottage industries, and commercial businesses.

<u>2.4.1 Agricultural applications</u>

In the area of agriculture solar PV is found to be useful for applications such as water pumping for irrigation and cattle drinking, aeration for aquacultures, refrigeration of agricultural products, electric fencing, poultry lighting, and pest control. The main impacts of solar electricity on agricultural activities are described as increased productivity (including higher yields, lower losses and faster production) and improved natural resource management (VAN CAMPEN et al 2000). The relevance of small PV systems for agricultural production is, however, limited to the provision of power for activities that require little power input. PV systems are not an option for energy intensive activities such as in rice mills and other agricultural processing (VAN CAMPEN et al 2000).

<u>2.4.2 Applications in cottage industries and commercial industries</u>

For cottage industries and commercial businesses, the most common reported examples of productive use are related to the prolonged working hours due to lighting. Lighting is reported to improve also the quality of the productive activity and to attract more customers, according to the nature of the business. To less extend PV systems are also used for providing power for music, TV and simple devices for these businesses as well as the powering of small monitoring devices and tools in electronic repair shops which can improve the quality of repair and the productivity of the workshop with very limited power demand (VAN CAMPEN et al). A GTZ project in Mongolia reported the use of an inverter for a milk centrifuge (VEIT 2006). Other applications include the sale of electricity or related services. Examples are solar battery charging stations, rural telephone and internet services, as well as recreational service businesses such as small village cinemas and dancing halls. Positive impacts on cottage industries and commercial businesses include longer working and opening hours, higher productivity, higher attractiveness for customers, more employment, and the creation of new productive activities (VAN CAMPEN et al 2000).

<u>2.4.3 Restrictions of solar PV for productive use</u>

While solar PV seems appropriate for household lighting and applications that use small amounts of electricity, it may not be suitable for promoting productive applications on a large-scale (e.g. machines for industrial manufacturing processes), largely because of the high costs of delivered electricity involved (KAPADIA 2004). Still, the small-scale productive application of small loads from solar PV systems seem to be potential “carriers of rural socio-economic development” (VAN CAMPEN et.al. 2000).

3 Solar Home Systems

The Solar Home System is by far the most popular and numerous application of PV technology in Bangladesh. Tapping productive potentials of this technology might therefore result in immediate impacts on a far larger scale compared to the introduction of a completely new technology. This chapter will provide an overview on international experience with productive uses of SHS, summarize current productive applications in Bangladesh and elaborates about potentials as well as barriers for tapping them effectively. Eventually paragraph 3.4 will give recommendations for the future promotion of productive SHS applications.

3.1 Review on International Experience

3.1.1 General Experience

Solar PV systems for household use - typically called solar home systems (SHS) – constitute a good replacement for kerosene lamps and car batteries, providing substantially improved quality of electricity service. They tend to be typically small in capacity: in a global study of SHS installations, NIEUWENHOUT et al (2002), calculate that about half of all installations covered in their study fall in the range of 35-54Wp. In the same study, it was determined that 93% of the systems installed were used for powering lights alone, or for running lights, DC televisions and radios for a few hours every day. Of course, SHS provide considerable health benefits by displacing harmful emissions from kerosene lamps, the luminosity and quality of light is immensely better, making it much easier to carry out household chores and reading and studying activities. If they replace car batteries, SHS help save much time and effort involved in hauling acid-filled, short-lived car batteries to battery charging stations every few weeks (KAPADIA 2004).

Quantitative information on the extent of productive activities or income generation facilitated by SHS is hardly available. Most information is based on anecdotal evidence from project reports and publications. The impact of SHS on overall economic development is therewith very difficult to estimate. SHS projects from around the world report income-enhancing opportunities including keeping shops open or carrying out activities such as basket weaving or sewing for a few extra hours every evening. Furthermore, in many cases mobile phones are charged for rural communications businesses (KAPADIA 2004).

Two unique examples of promoting productive use of SHS in South Asia shall be briefly presented: the introduction of electric sewing machines in India through SELCO and the Home Employment Lighting Programme (HELP) in Nepal.

3.1.2 Introduction of electric sewing machines in India (SELCO)

One not yet very widespread productive potential of SHS is the introduction of simple electric sewing machines: their usual energy requirement is about 50-75 Wh/day for a sewing machine of 80W power rating. These applications can easily be powered by slightly increasing the size of PV systems for lighting and radio/TV (the marginal costs of 10-20 Wp extra power are low) and could not only save time but also create more productive tailors (VAN CAMPEN 2000). A prominent example for the use of sewing machines is SELCO-India. SELCO is a private business which sells SHS to households and institutions in India. After winning the Ashden Award for enterprise, SELCO used part of the price money to set up a small innovation department, tasked in particular with finding new ways to promote income generation among its customers. One of its first projects was the introduction of PV-powered sewing machines to increase productivity of sewing businesses (SELCO 2007). The project focused on replacing traditional motorized 150W sewing machines in areas with grid connection with more efficient 105W machines powered by grid-solar hybrid power. Besides reducing the monthly electricity bill, the new machines were equipped with additional features such as embroidery and button holing. Users were trained to use these new features and could therewith gain new business opportunities for embroidery work. Interruption of production during power cuts could be avoided. Initial studies suggest that the average daily income increased by about 50 Indian Rupees; the overall payback period for the initial investment was about 2-3 years. The SELCO project proved the technical feasibility of running small sewing machines with SHS. However, as the employed systems were also connected to the national grid and PV electricity only used for a few hours per day, this approach might not be replicated in the same way for off-grid areas in Bangladesh.

3.1.3 The Home Employment Lighting Program (HELP), Nepal

Another innovative approach to promote productive use of SHS is the Home Employment Lighting Program (HELP), an initiative of the Himalayan Light Foundation (HLF) in rural areas of Nepal. The program intrinsically combines the dissemination of SHS with the promotion of income generating activities. Villagers participating in HELP are offered skill-training to set up an income generating activity such as knitting, weaving, producing handmade paper products, painting etc. and a SHS to extend the working day. The program contains an additional e-commerce component to create a national and international market for the products (HLF).

3.2 Existing Productive Uses in Bangladesh

When it comes to solid quantitative information on productive uses of SHS in Bangladesh, the situation on international level is reflected. Information sources are scarce, most are of anecdotal nature. The POs that were interviewed for this study were neither systematically collecting data on the use of provided electricity nor on the types of SHS customers (commercial, domestic, etc.). The following overview on ongoing productive applications is therefore mainly based on subjective perceptions and estimations of respective stakeholders involved in SHS dissemination as well as field observations.

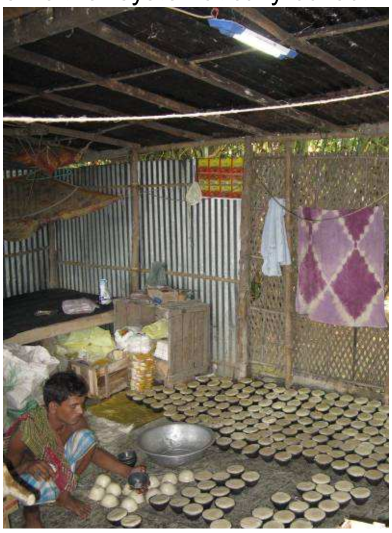

Figure 1: Solar lighting in a soap factory enables longer production hours. Photo: Michael Blunck

3.2.1 Household level

It is estimated that between 85% and 95% of all SHS are used in households. All available information sources confirmed that currently most domestic SHS are not used for income-generating purposes but for lighting and entertainment. However, in some cases the electric light is used to extend working hours and save kerosene expenditures for existing small cottage industries such as handicraft production (cp. Figure 2), sewing, stitching, weaving or preparation of rice cakes. In one case during a field visit the SHS light was found to be used to extend the production time of a small local soap factory (cp. Figure 1). It is notable that the majority of households do not seem to start a new cottage industry due to the installation of the SHS, but extend working hours of existing activities. The percentage of households using their SHS for this purpose seems to vary significantly among different parts of the country, depending on factors such as the existence of traditional cottage industries and market access of the respective areas. The overall percentage of households using their SHS for the lighting of small cottage industries was estimated by most of the interviewed stakeholders to be between 10% and 15%.

3.2.2 Existing shops and small businesses

Figure 2: Solar lighting increases production hours for small handicraft industries. Photo: GS

It is furthermore estimated that about 5-10% of all existing SHS have been purchased by shops in local village markets. The electric light enables shopkeepers to keep their shops open longer in the evening, in many cases between 2 and 4 hours can be gained (cp. Figure 3). Along with improved lighting, the use of TV in restaurants and grocery shops increases customer attraction and therewith daily income. Furthermore, some existing shops and new stand-alone businesses now offer new electricity-based services such as mobile charging or telephone services. Field observation revealed that mobile charging services may provide an additional monthly income of about 300 BDT, which represents a significant share of the monthly instalments to be paid for the SHS. Notably, many tailor shops use the SHS to increase their daily working hours. SHS were also used in other small business such as barber shops or bicycle repair shops. All interviews with businessmen during field visits confirmed that the economic impact of SHS on shops and small businesses in local markets was rated very positively, even though most businessmen were not able to give an estimate for the quantitative increase in production or income.

3.2.3 New business opportunities

Few new business opportunities seem to have developed due to the introduction of SHS. Through initiative of GS the so-called 'micro utility' business was introduced in a number of rural village markets. Shops and businesses with SHS rent out single lamps against a monthly fee of about 200 BDT to neighboring businesses. Through this model the businessmen can already cover a significant share of their own monthly SHS instalments and receive a steady monthly income after the payback of their loan. In some cases GS introduced small solar-powered soldering irons that are used in newly established electronic repair shops. The number of these businesses still tends to be low, with a maximum of one shop in a market. Before the introduction of SHS, these shops could only be found in bigger towns with access to grid electricity. Some POs report that 75 Wp SHS are in individual cases used to power small village cinemas consisting of a TV and Video-CD system which had the potential to generate about 10,000 to 15,000 BDT per month.

Figure 3: Solar lighting enables longer opening hours in shops. Photo: Michael Blunck

3.2.4 Agricultural applications

In the agricultural sector, SHS are found to be used for lighting of poultry farms (cp. Figure 4) and fish ponds. As the maximum productivity of poultry farms can only be achieved with a daily lighting amount of 16 hours, most poultry farms in off-grid areas use large amounts of kerosene for lighting purposes. A poultry farm in Phulpur district reported a productivity increase of 5-10% and monthly savings due to reduced kerosene costs of about 4,000 BDT Taka after installing a SHS and three CFL lights. In Phulpur district, 26 (1.3%) of the total number of 1,970 SHS installed by GS and RSF were found to be used in poultry farms. A small number of 4 systems were used to provide lighting for fish ponds. Electric lighting in fisheries was described to decrease the risk of theft.

**Figure 4: Lighting in poultry farms can significantly increase productivity.
Photo: Michael Blunck**

3.3 Potentials and Barriers

3.3.1 SHS for domestic income generation

As the figures in the last paragraph imply, the productive potential of domestic SHS seems not to be fully tapped as yet, as 85-90% of all households with SHS do not use their system for income generation. An increased use of SHS for domestic income generation would be desirable. However, there are several barriers that have to be considered. On one hand the processing of agricultural goods (e.g. rice threshing) is one of the most common productive activities found in rural Bangladeshi households. SHS do not provide enough power to drive machinery used for activities related to agricultural processing. On the other hand, depending on the respective local context the number of existing cottage industries in rural Bangladesh is generally low. Apart from electricity, other more significant factors such as lack of business skills and access to national and international markets significantly hamper the development of rural cottage industries. Furthermore, households purchasing a SHS are in general economically much better off than other households of the same community. Many SHS households possess land, have family members with good regular income (e.g. NGO worker, remittances) and/or run small local businesses. It can be observed that many households with SHS are therefore not very interested in starting small income-generating activities in the evening hours as this time is mostly used for watching TV, studying of children or household-related work.

3.3.2 SHS for small rural businesses

As the current percentage of SHS used in small rural businesses, e.g. for extending working hours in rural markets or increasing the productivity of poultry farms, is still very low even though the economic impacts seem to be significant, an increased use of solar lighting in small rural businesses would be eligible. The main barrier for further dissemination of SHS among rural businesses is the limited interest of POs in targeting those rural enterprises within their marketing campaigns. As the POs' main interest is not necessarily the promotion of income-generating activities, many of them are mainly targeting domestic customers. As the overall demand for SHS is still very high, POs are not in the need of carrying out particular marketing activities focusing on local businesses. Furthermore, as the lighting demand of small shops is often well below the capacity of standard 50Wp SHS (systems below 30 Wp were until recently not included in the IDCOL programme), this market segment was in the past not served with an appropriate SHS product. By introducing small SHS (SSHS) below 30Wp in early 2008, a first step was taken to reach more shops and small businesses. Experience from POs revealed that the percentage of SHS used for income generation is significantly higher among SSHS customers. On one hand the small systems are now affordable to households that are more dependent on household-level production; on the other hand these systems cater much better to small shops that are often only in need for good quality lighting to extend opening hours, but do not need higher loads for several lamps or a TV.

3.3.3 New productive appliances for SHS

Another potential for increased productive application of SHS might be the introduction of new productive appliances to enable new types of businesses and increase productivity of existing activities. As the power output of SHS is limited and the extension of existing systems would involve significant upfront investments, only very few options seem to possess realistic potential in this regard. As the model of SELCO in grid-connected areas of India showed, efficient **electric sewing machines** can be powered by SHS by slightly increasing the system's power output. Experience by the Centre for Mass Education in Science (CMES) – one of the POs within the IDCOL programme – revealed that small 50W sewing machines can technically be used even with existing SHS. However, interviews with stakeholder from the SHS sector as well as field observations revealed major barriers for the successful introduction of this technology in Bangladesh. Foot-driven pedal sewing machines are widely in use in the rural areas. As most locally produced clothes do not contain complex embroideries it is questionable whether the introduction of electric machines – besides making the work easier – would have a significant impact on productivity and income. As the purchase of a new sewing machine would constitute a significant investment for small rural tailoring businesses and the economic benefits seem to be rather small, the demand for the technology is expected to be very low. The same is true for a small **drill machine** for small workshops developed by CMES. Even though technically feasible, the investment cost for the SHS as well as the drill machine has shown to be disproportionate to only minor economic gains. Prof. Sadrul Islam of the Islamic University of Technology conducted research on the technical feasibility of small **refrigerators** powered by solar PV that might be used in rural medicine shops. The system set-up (6 x 75Wp PV panels) needed to power one 95W refrigerator already points out the high investment costs (about 200,000 BDT) that are by far much higher than any potential increase in income gained by this new technology. In a nutshell: even though some technologies for productive use of SHS are available, their high investment cost in proportion to modest potential effects on productivity and income is the main barrier for their widespread utilization in rural Bangladesh.

3.4 Recommendations

Given the existing potentials and barriers the following recommendations for further increasing the share of SHS used for productive purposes can be derived:

- To gain a realistic overview on productive uses of SHS, a solid quantitative information base on existing types of customers and respective productive SHS applications should be created. Therefore, a comprehensive customer survey among customers from all IDCOL POs is highly recommended.

- To increase the number of productive activities in households, close cooperation with local stakeholders in the area of SME/cottage industries promotion is recommended. Organizations like the Palli Karma-Sahayak Foundation (PKSF) and their network of partner NGOs are already providing business development services and training to rural entrepreneurs. Some of PKSF's partners are even already working within the IDCOL SHS program. Especially those partners should be motivated to combine existing business development trainings and financing with their SHS activities, e.g. by including awareness raising on the productive potentials of SHS in training curriculums or offering special financing products for start-up businesses interested in purchasing a SHS to extend available production time.
- As many POs are currently not facing the particular necessity to promote SHS among rural businesses, they are mainly targeting rural households. To increase the share of SHS among rural businesses such as shops, restaurants, poultries, etc. incentives through IDCOL, such as bonus payments or a higher grant percentage for SHS in rural businesses could be introduced. Furthermore, initiatives such as a 'Solar Productivity Award' for POs particularly successful in promoting productive use might be thinkable. Such initiatives, however, would as well involve higher costs for regularly monitoring respective productive activities.
- Success stories such as GS's micro utility model should be actively shared and promoted by IDCOL.
- As the use of SHS in off-grid poultry farms seem to yield particular high economic benefits, intensified cooperation with national and local poultry associations should be considered to increase awareness and share good experiences among their members.
- It is recommended to strongly promote small SHS – potentially by introducing further incentives through the IDCOL program – as their share of productive application (mainly lighting of small shops) seems to be significantly higher compared to the standard systems.

4 PV pumping

Besides the use of SHS, the application of PV technology for water pumping has been discussed in Bangladesh for several years. However, initiatives to promote this technology have so far been relatively few. This chapter will provide a brief overview on international experience with PV pumping, present recent experiences in Bangladesh, identify barriers for the technology's wide dissemination and give recommendations for the way ahead.

4.1 Review on International Experience

Solar PV pumping for irrigation and lifting of drinking water is a matured technology which has been tested in a number of countries around the world. Over 50,000 PV pumping systems are in operation worldwide (ISLAM 2006). As this study focuses on income-generating activities, experiences on solar pumping will concentrate on applications for agricultural irrigation.

4.1.1 General Experience

VAN CAMPEN et al (2000) summarize experiences from several country cases. A general finding is the fact that investment costs in PV pumping equipment are much higher than the alternatives (diesel, electric), but on a life-cycle basis, PV pumping can be economically more competitive. The relative advantage of PV pumping is in the low-water use and low pumping head (low power) range. Other advantageous aspects are low maintenance and high reliability if projects are well designed and organized. PV pumping is therefore very suitable for drinking water supply in remote unelectrified villages and often the least-cost solution on the basis of life-cycle costing. Also, for livestock watering, PV pumps are often the least-cost solution and widely used. Since irrigation often takes part only part of the year, the demand for water is more variable, with peaks in a specific period. PV pumping systems have to be oversized to meet these peak demands, which makes them under-utilized for other months. Such water requirements for part of the year favor powered pumps that require a low initial investment, such as diesel pumps. This disadvantage of PV systems for seasonal irrigation could be cancelled out, if additional uses for the PV power supply could be found for the non-productive part of the year when irrigation is not required.

HAHN (1998) at al summarizing experiences of GTZ's past PV pumping pilot projects, describe under what site-specific conditions the use of photovoltaic pumps for small-scale irrigation can offer economic advantages over competing technologies:

- arid/semi-arid climate;
- no access to the public power grid;
- problems with the maintenance of diesel pumps and the supply of fuel for their operation;
- low pumping head (maximum of roughly 30 metres);
- small field sizes (maximum of three hectares);
- cultivation of high-quality crops for secure markets;
- use of water-conserving and energy-saving methods of irrigation (e.g. drip irrigation);
- high degree of system utilization through adoption of permacultures or systematic crop rotation.

PV pumping systems have proven particularly well-suited for water- and energy-saving methods of irrigation such as drip irrigation because of their advantage in the low-energy range. This has particular advantages in areas with water scarcity, but requires extra training in the use of improved irrigation techniques, especially in regions where little experience exists with such improved techniques. Experience from India (see below) shows that with proper training and management large savings on water and fertilizer can be made, with raising crop performance.

Many of the same advantages and barriers that apply to PV systems in general, also apply to PV pumping systems. A specific characteristic of PV pumping systems is that they generally do not need a battery for back-up, but can use a water tank for storage, reducing investment and maintenance costs and increasing system reliability. High system reliability is particularly important in combination with water saving irrigation techniques (VAN CAMPEN et al 2000).

4.1.2 PV pumping in India

For the case of Bangladesh, experiences on PV pumping systems from its neighbor country India can provide important conclusions for future initiatives as already more than 6,800 Photovoltaic pumps are operated there with the aid of subsidies and soft loans introduced by the Ministry of Non-conventional Energy Sources (MNES) (ISLAM 2006). In the introductory phase, the most common irrigation system was a 900 Wp surface mounted pump, costing around US$6,250 (including electronics, pump and installation excluding irrigation equipment). At present, financial incentives include a soft loan (5 %) and a subsidy of US$3 per Wp up to US$5,000. For the described 900 Wp-system, this would mean a subsidy of approximately 40%. MNES also supports training programs on operation and maintenance and water management aspects of the PV pumping systems. These cover the actual users, local technicians and rural youth (VAN CAMPEN et al 2000).

The experiences in the Indian program can be described as mixed. The installation of large numbers of PV pumping systems has led to a wealth of experience both in the technical, financial and organizational field. Most of the installed systems are working satisfactorily and niche markets for the use of PV irrigation systems seem to be increasing, mainly for horticulture and other high value crops and in combination with water saving irrigation techniques. The adequate use of drip irrigation systems can save both water and fertilizer, increase production and augment the viability of PV pumps (due to lower water, i.e. energy demand). Research conducted by the Central Plantation Crops Research Institute (India) led to the conclusion that through such irrigation techniques the use of Nitrogen fertilizer could be reduced to 1/3, phosphatic fertilizer to 1/10 and potassic fertilizer to 2/5. In addition to an 80% reduction in fertilizer expenses, crop performance improved. With the aid of appropriate financing mechanisms, private sector companies have been included in the project, laying the basis for sustainable markets. On the other hand, markets are developing much slower than anticipated and high investment costs continue to be a major obstacle for the widespread use of such systems. Appropriate subsidy and financing mechanisms will continue to be necessary for the time being to lower this barrier. The experience has also shown that the introduction of PV technology must be combined with adequate technical support infrastructure and training programs in improved agricultural and irrigation practices, including adequate field preparation, correct water management and selection of adequate (high value) crops. A final conclusion from this experience is that the above-mentioned technical and agronomic assistance should be made available to the farmers from one source (one institution) to facilitate the adoption of PV-powered irrigation equipment and improved irrigation techniques (VAN CAMPEN et al 2000).

4.2 Experience with PV pumping in Bangladesh

In Bangladesh, till date, the experience with PV pumps at field level is very meager and has been limited to a few technical demonstrations and tests. Most of the following information was gathered from ISLAM (2006), who provides a detailed overview on Bangladesh's experience with PV water pumps.

4.2.1 First technical demonstrations

A first technical demonstration of the PV pumping technology with a small (0.1 cusec) pump with foldable panel in 1982/83 by an ex-hydro-geologist, who once worked with the World Bank, proved the technologies technical potential. The system was later handed over to the Bangladesh Agricultural Research Institute (BARI) and tested for growing various crops. The initial findings were quite encouraging. However, the interest of the Government slowed down with falling oil prices to less than US$ 16-18/bbl. The overall interest in Renewable Energies during the Eighties became later a relatively low priority issue.

4.2.2 The REB Narsingdi project

The first large 1.68kWp water pump was presented to the Rural Electrification Board (REB) by the Government of India in 1998 in the area of the Narsingdi SHS pilot project. The technical specifications were as follows:

- **Panel/Array Capacity:** 1680 Wp (48 x 35 Wp Panels)

- **Pump type**: Variable speed A.C. Motor + Inverter, Maintenace-free Capsule Mono-submersible, Pump (Make : Grundfos)
- **Flow capacity (Q):**: 40,000 litres/on a clear sunny day
- **Total Head (H)**: 100 meter
- **Market price**: US$ 10,000

This type of pump is being routinely used in India to supply drinking water from about 250 - 300ft deep water wells, which work with least care and maintenance for years. The pump ran successfully and almost uninterruptedly from the very first day till its dismantling by REB, due to shifting of the Pilot Project site, after the grid reached there. After dismantling of the Karimpur Central Charging Station in 2001/02 this demonstration unit has been stored at REB. Currently, there are plans to install the system at a REB training site in Savar.

4.2.3 Advanced technical demonstrations

The Mechanical Engineering Department of Bangladesh University of Engineering & Technology (BUET), led by Dr. Rashid Sarkar and his team at the Energy Research Centre, BUET, conducted a number of testing/evaluation works with a 80 W PV pump (2x40 Wp), which ran a 24 Volt DC Motor, with a capacity of 450 liters/day. The objective was to test the suitability of this pump for use in lifting small quantities of drinking water in remote off-grid places. The results of the tests of BUET were quite encouraging. The PV pump could successfully lift water to an overhead tank, which was installed on the roof-top of a 6-storied building. The final conclusion of the BUET team was that the PV pump can successfully be used for lifting small quantities of water and could therewith be applicable for water conserving irrigation in remote off-grid areas.

Demonstrations/Experiments are also being conducted at the Renewable Energy Research Centre (RERC), Dhaka University with small pumps, limited to academic works. ‘Demos’ of small pumps (50Wp - 250Wp) were organized at PV Exhibitions by a number of institutions, like the Local Government Engineering Department (LGED), BUET, RERC, Dhaka University and also by some private sector companies on various occasions in connection with Solar / RE Exhibitions. However, all the above works have been limited to technical demonstrations and for academic interests only.

4.2.4 The Barind pilot project (LGED)

The first large-scale pilot project on the use of PV water pumping was installed, tested and commissioned at four Eco Villages in the Barind area, near Rajshahi. The project was launched by LGED under its Sustainable Rural Energy (SRE) program funded by the United Nations Development Programme (UNDP). After initial testing and commissioning, the installation was handed over to the Barind Multipurpose Development Authority (BMDA) in 2004/5, which is now maintaining and monitoring it. The project installed two 1.8 kWp (cp. Figure 5) and two 1.2 kWp systems with 26,000 liters and 13,000 liters of daily flow respectively. Each pump lifts water to a 10,000 liter capacity overhead water tanks for storage and supply of drinking water to about 30 - 40 families and have dynamic heads of about 50 meters. The total project costs were about 2,800,000 BDT. Technically, no problem with the PVP Pilot project has been reported. As the high investment costs were covered by the project, no model for demonstrating the financial viability and sustainability of the project was introduced.

Figure 5: 1800 Wp PV pump in Nachole. Photo: Islam

4.2.5 Current and future initiatives

A small number of further pilot projects are to be expected within the near future. Rahimafrooz has just recently started a promising drinking water pilot project in cooperation with the Australian company ‘Mono’ to develop an economically feasible operation model. The project is executed by the NGO ‘Dipshika’ in Dinajpur. No extensive experience is available from that project yet. CMES is expecting to start a pilot project on PV irrigation in 2009, incorporating CMES’ previous research and experience in the field of drip irrigation techniques.

Summarizing existing experiences with solar PV in Bangladesh, it has to be stated that apart from technical demonstrations of successfully operating the technology, there is a lack of pilot projects going one step further by demonstrating sustainable financial and management models.

4.3 Potentials and Barriers

4.3.1 Potentials

Good amounts of solar insolation (4 – 7 kWh/m^2/day with about 300 days of annual sunshine hours) combined with an irrigation-based agriculture (65% if all cropped areas are under irrigation), unreliable grid power supply, rising fuel prices, high public expenditures on diesel subsidies, low pumping heads, small field sizes generally mark very good preconditions for the introduction of solar pumps in Bangladesh.

Of the 2 million tons of high speed diesel oil (HSD) consumed in Bangladesh annually, about 40% is consumed for powered (mechanized) irrigation. A smaller quantity of HSD is used for larger diesel engines for operating deep tube-wells. In the North Bengal area, especially the 'Barind' areas of Rajshahi, Bogra, and Rangpur, where rainfall is limited, most of the deep tube wells have been electrified. However, the small to medium low lift pumps and the shallow tube-well pumps are still used in large numbers (about 1.25 million units) all over Bangladesh (ISLAM 2006). ISLAM (2006) identified the replacement of about 1.15 million units of small (4 H.P.) diesel low lift pumps as the potential target market for PV surface irrigation in Bangladesh.

Most potential stakeholders in the dissemination of the PV irrigation technology (IDCOL, POs, REB, LGED) are confident that PV pumping should be the next large-scale PV application in Bangladesh. Given a technically, socially and economically viable dissemination model is identified, IDCOL would in general be willing to offer a financing scheme and include the financing of PV pumps into their product portfolio. Many POs stated to be interested in taking part in respective pilot projects and large-scale dissemination programs.

4.3.2 Barriers

There are, however, still several barriers hindering the immediate large-scale dissemination of PV pumps in Bangladesh. The most significant barrier is the **high initial investment costs** for the pumping system. Even though international experience has shown that well planned PV pumping projects – when taking the whole operation life into account – can be economically competitive compared to diesel systems, the initial investment is still a major drawback for rural farmers. As DC submersive water pumps are not produced locally, they have to be imported from China or India increasing the overall system costs. Pilot projects with detailed assessments on system economics are hardly available causing uncertainty among potential investors. There are currently no financial products available that are tailored to the needs of investors in PV pump systems. Incentives such as grants or soft loans are non-existent. It is therefore very unlikely that rural farmers at this moment would take the risk of investing in a – for them – unknown technology.

Besides technical demonstrations, there has not yet been any detailed research to develop a **sustainable dissemination model for PV pumping systems**. Taking the IDCOL SHS dissemination as a good example, such a model should include systematic approaches regarding technical system configuration and standards, financial mechanisms, system management, operation and maintenance. Interviews with potential stakeholders for a future PV pump dissemination program revealed that most stakeholders – even though highly interested in the technology – are currently waiting for initiative from outside their own organization to come up with pilot projects and a sustainable dissemination approach. Limited availability of funds and technical expertise seems to be the main reason for this passiveness.

A third factor that might potentially hinder the quick dissemination of PV pumps is the **prevalence of water-intensive irrigation practices** throughout the country. Due to the high costs of a PV system, water-saving irrigation techniques should be introduced together with the PV pumps. As water-saving irrigation techniques are not yet widely in use (except from vegetable production in the north of the country), the introduction of PV pumps might not be economically viable without changing to less water-intensive cropping techniques, e.g. for traditional water-intensive irrigation systems such as rice. Besides saving irrigation water such water-saving irrigation might even result in further positive impacts, as scientists are claiming that most of the rice cultivation is currently carried out with too much irrigation water, which is effectively reducing yields.

4.4 Recommendations

From the potentials and barriers described in 4.3 the following recommendations for the promotion of PV pumping systems can be derived:

- More practical research on economies of PV irrigation systems as well as the demonstration of successful technical, financial and managerial set-ups is needed. It is therefore highly recommended that the Government of Bangladesh, IDCOL, foreign donors or the private sector provide financing and technical expertise to organizations interested in setting up sustainable pilot schemes. The provision of technical expertise might include the exploration of available technologies, technical trainings or exposure visits to successful PV pumping projects abroad (e.g. in India). It has to be highlighted that such pilots should go well beyond demonstrating the technical feasibility of PV water pumps but include economic and social aspects of sustainability.
- Local Agricultural Research Institutions should be closely involved in the development of the pilot schemes. They should develop appropriate water-saving irrigation techniques and provide trainings to farmers involved in the pilot project.
- Experience from these pilot projects should then be used to develop a replicable dissemination model which could be applied similarly to the IDCOL SHS approach. This includes the provision of financing through soft loans and grants to facilitate the introduction of PV pumping systems in the market, sourcing of technical equipment, technical standardization, trainings for technicians and customers, and monitoring activities.

5 Other productive applications of PV technology

Besides the increased productive use of SHS and the application of solar water pumps, there are two more potential areas for productive applications of solar PV technology in Bangladesh. Both of them are, however, still based on first ideas without any significant experience from the field level.

5.1 PV pond aeration

Aeration of ponds is of most utmost importance for the health of aquatic animals such as fish and shrimp in intensive aquacultures. In highly intensive aquaculture, continuous aeration is a common management strategy. Very high production rates in both shrimp and fish culture have been achieved with the use of continuous pond aeration (HOWERTON 2001). Fish and shrimp production constitutes 4.91% of Bangladesh's GDP. Fish and fishery products are the country's third largest export commodity contributing 5.10% of its exchange earnings (FAO 2008). As aquacultures play a significant part for the livelihood of many Bangladeshis and many fisheries and shrimp farms are not connected to the national electricity grid, one might consider the use of solar PV for aeration of ponds. A very first small pilot was initiated by Prof. Sadrul Islam of the Islamic University of Technology but was later cancelled due to lack of financing.

There are an estimated 1.3 million fish ponds in the country, covering an area of 0.151 million ha. Traditional methods of fish culture in ponds do not use external inputs. Ponds are filled by rain or by opening sections of the embankment to allow ingress of floodwaters. The average harvests from these types of ponds is very low (700 kg/ha), in more recent years pond aquaculture has gained importance through its growing ability to increase production levels. Polyculture of native and exotic carps is a popular technology used by many farmers throughout the country, in such systems pond preparation, species selection, stocking density, the application of feed, fertilizers, water exchange and proper husbandry are generally maintained. In general fish culture in Bangladesh is characterized by the use of both extensive and semi-intensive systems (FAO 2008). A field trip to a semi-intensive fish farm near Mymensingh revealed that aeration of ponds is in use in some farms. However, for optimal productivity, demand for aeration is limited to about 2-3 hours per night. Aeration is carried out with diesel and electric water pumps by showering water on the pond surface. In case of larger ponds, speedboats are sometimes in use.

Shrimp farming in the south and southeastern coastal belt of Bangladesh began in the early 1970s. From less than 20,000 ha of brackish water ponds in 1980, the area under cultivation expanded to approximately 210,000 ha by 2008. Traditionally shrimp farming began by trapping tidal waters in nearby coastal enclosures known as 'gher' where no feed, fertilizers or other inputs were applied, with an increasing demand from both national and international markets some farmers started to switch over into improved extensive and semi-intensive systems. Shrimp farming is a capital intensive business with total production costs of US$ 735 per ha/crop for extensive system, US$ 1,837 per ha/crop for improved traditional systems and US$ 9,184 per ha/crop for semi intensive systems, the corresponding net income however is US$ 1,275, US$ 2,204 and US$ 153,061 per ha/crop respectively (FAO 2008). Currently the shrimp sector in Bangladesh is facing an enormous underutilization of processing capacity which is 300,000 t compared to an annual production of 50,000 t, which is mainly due to untapped intensification potentials of production.

Due to the very extensive traditional techniques of aquaculture, the current potential for the dissemination of solar PV aeration systems in Bangladesh is still very little. Even in places where grid electricity is available, aeration is not widely in use or limited to a few hours at night. Permanent aeration is only beneficiary in intensive and highly-intensive aquacultures which include high levels of fertilization and supplemental feeding (HOWERTON 2001). Dr. Aftabuzzaman – aquaculture specialist and former chairman of the Bangladesh Frozen Foods Exporters Association – confirmed that aeration of existing traditional extensively cultivated ponds will not result in any significant productivity increases. The introduction of PV aeration systems could therefore only support an ongoing large-scale shift from extensive to intensive cultivation techniques. However, such a large-scale investment in aquaculture productivity certainly needs support by the Government of Bangladesh and/or financial institutions as investment costs are very likely to exceed local farmers' financial capabilities. Furthermore, ecological issues related to highly-intensive aquacultures have to be considered.

At this time, the introduction of PV-powered aeration systems for aquacultures in Bangladesh does not seem to be reasonable as for existing aeration systems the low utilization time of only 2-3 hours per night is highly unlikely to be economically sound considering the high investment costs of a PV system and the additional need of battery storage; for existing traditional pond cultivation an effect on productivity through the introduction of aeration systems is highly unlikely. In case of an increase of intensive and highly-intensive aquacultures within the next years, the promotion of PV-powered aeration systems could be reconsidered.

5.2 Productive applications in PV mini grids

As the limited amount of provided energy is the major drawback for productive applications of SHS, central PV mini grids might constitute an option to provide larger loads to small rural businesses. Up to today LGED has installed two central PV mini grids in Bangladesh, one in a local growth centre of Gangutia in Jhenaidah district, the other in a coastal fishermen community in Sariakhali of Cox's Bazar district. There is unfortunately no detailed documentation on LGED's experiences from both of the projects. The mini grid installed in the Gangutia growth centre consisted of a 1.8 kWp PV system serving 45 shops, 3 food processing and small industries as well as one community centre. Detailed information about the electrified small industries and the impacts on productivity is not available. However, given the larger amount of electric loads provided in a PV mini grid the potentials for productive uses are very likely to be much higher compared to a stand alone SHS.

IDCOL plans to set up a pilot village-level PV mini grid within the next 2 years. POs might invest in the mini grid and then sell the power to the individual customers. It depends on further field level experience from such pilot schemes whether further involvement of the GOB or donors in the area of PV mini grids might prove reasonable. At this time, financing and technical support for individual pilot initiatives is recommended.

6 Conclusions and Recommendations

The findings from this study on productive potentials of PV technology in Bangladesh lead to the following main **conclusions**:

- Detailed information on existing productive uses of SHS in Bangladesh is still very limited and mainly bases on assumptions and anecdotal field experience.
- Most SHS on household level are not used to extend productive working hours, the main reasons being a) limited business skills and market access hampering general cottage industry development and b) nonexistent need for additional income as wealthier SHS customers already have good sources of income.
- Limited promotion of SHS in rural businesses is a major drawback for productive applications such as lighting of poultries and fisheries
- The productive use of small SHS seems to be significantly higher compared to standard systems as the small systems seem to be best suited for the lighting of small shops.
- Apart from small soldering irons for niche markets, there are currently no cost-effective productive appliances available for the SHS. In all observed cases, investment costs were significantly higher than any economic benefit gained by the use of the respective appliances.
- Given sufficient initiative from respective stakeholders, solar PV pumping could gain significant importance in Bangladesh. The main existing barriers are the nonexistence of financial options to cover initial investment costs, a lack of sufficient pilots and research on sustainable financing, management and operation models as well as the fact that water-saving irrigation techniques are still rare throughout the country.
- At this time, the introduction of PV-powered aeration systems for aquacultures in Bangladesh does not seem to be reasonable as an effect on productivity in traditional pond cultivation is highly unlikely. In case of an increase of intensive and highly-intensive aquacultures within the next years, the promotion of PV-powered aeration systems could be reconsidered.
- There might be some potential for productive applications in PV mini grids, as they can provide larger loads to drive productive appliances and machines. Previous experience in Bangladesh is, however, still very limited and not well documented.

From these conclusions the following **recommendations** to decision makers from the GOB, international donors, NGOs and the private sector can be derived:

- To facilitate decision making, a solid quantitative information base on existing types of customers and respective productive uses of SHS should be created (household surveys, etc.).
- To increase the number of productive activities in households, close cooperation with local stakeholders in the area of SME/cottage industries promotion (e.g. PKSF) is recommended. The role of such stakeholders might include awareness raising on the productive potentials of SHS or the introduction of financing products for start-up businesses interested in purchasing a SHS to extend available productive time.
- To increase the share of SHS among rural businesses such as shops, restaurants, poultries, etc. incentives through IDCOL, such as bonus payments or a higher grant percentage for SHS in rural businesses, might be thinkable. Furthermore, initiatives such as a ‘Solar Productivity Award’ for POs particularly successful in promoting productive use might be introduced.
- Success stories such as GS’s micro utility model should be actively shared and promoted by IDCOL.
- As the use of SHS in off-grid poultry farms seem to yield particular high economic benefits, intensified cooperation with national and local poultry associations should be

considered to increase awareness and share good experiences among their members.

- It is recommended to strongly promote small SHS – potentially by introducing further incentives through the IDCOL program – as their share of productive application (mainly lighting of small shops) seems to be significantly higher compared to the standard systems.
- More practical research on economies of PV irrigation systems as well as the demonstration of successful technical, financial and managerial set-ups is needed. It is therefore highly recommended that the Government of Bangladesh, IDCOL, foreign donors or the private sector provide financing and technical expertise to organizations interested in setting up sustainable pilot schemes.
- Local Agricultural Research Institutions should be closely involved in the development of the pilot schemes for PV irrigation. They should develop appropriate water-saving irrigation techniques and provide respective trainings to farmers in the pilot project.
- Experience from PV irrigation pilot projects should be used to develop a replicable dissemination model which could be applied similarly to the IDCOL SHS approach. This includes the provision of financing through soft loans and grants to facilitate the introduction of PV pumping systems in the market, sourcing of technical equipment, technical standardization, trainings for technicians and customers, and monitoring activities.
- PV mini grid pilot initiatives should be supported with financing and technical assistance, as the productive use potential within these PV mini grids is likely to be higher than with stand-alone SHS.

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Appendices

A1 List of conducted interviews

Date	Name	Position
September 7, 2008	Prof. Dr. M. Rezwan Khan	Vice Chancellor, United International University (UIU)
September 8, 2008	Mr. Nazmul Haque	Director & Head of Investment, Infrastructure Development Company Limited (IDCOL)
September 10, 2008	Mr. Ruhul Quddus	Executive Director, Rural Services Foundation (RSF)
September 11, 2008	Mr. Dipal C. Barua	Managing Director, Grameen Shakti
September 14, 2008	Mr. Munawar Moin Sohel Ahmed	Managing Director General Manager Renewable Energy, Rahimafrooz
September 15, 2008	Mr. Sudip Kumar Saha	Solar Programme Manager, Bangladesh Rural Advancement Committee (BRAC)
September 16, 2008	Dr. Muhammad Ibrahim	Executive Director, Centre for Mass Education in Science (CMES)
September 18, 2008	Prof. Sadrul Islam	Department of Mechanical and Chemical Engineering, Islamic University of Technology (IUT), Gazipur
September 23, 2008	Mr. Kaisar Ahmed	Coordinator for Renewable Energy Cell, Rural Electrification Board (REB)
September 24, 2008	Mr. Mir Tanweer Husain	Project Manager, Sustainable Rural Energy, Local Government Engineering Department (LGED)
October 16, 2008	Mr. Mosharraf Hossain Khan	Deputy Managing Director, Palli Karma-Sahayak Foundation (PKSF)
November 10, 2008	Mr. Md. Abul Bashar	Executive Director, Bangladesh Frozen Foods Exporters Association
November 10, 2008	Dr. Aftabuzzaman	Former Chairman, Bangladesh Frozen Foods Exporters Association

A2 Guideline questions for interviews with relevant stakeholders

Study on productive use of SHS
in rural areas of Bangladesh

- Guideline questions for qualitative interviews with POs and other organisations involved in SHS dissemination & research -

Organisation:	
Name of interviewee:	
Function:	
Date & Time:	
Place:	
Duration:	

General remarks on course of interview:	

Productive use of electricity = (indirect) use of electricity for income generation in households or businesses

General Information on Interviewee
1. **Role of organisation** regarding SHS dissemination?
2. Position, role and task of **interviewee**?

Assessment of IDCOL SHS programme
3. What are the **major successes** of the IDCOL SHS programme?
4. What have been the major **success factors** of the IDCOL programme?
5. What are the **weaknesses** of the IDCOL SHS programme?
6. How could these weaknesses be **approached by PO/donor** interventions?

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Assessment of current productive use of SHS
7. In what way are SHS currently used for income generation?
8. Give an estimate for the percentage of SHS currently used for this purpose!
9. What positive impacts does the use of SHS bring for the respective income-generating processes?

7.) Income-generating activity	8.) Percentage of SHS	9.) Positive Impact of SHS electricity					
		New products		Improvement of existing production / business			
		New activity	Added value	Product-ivity	Product quality	Productive time available	Customer attraction

10. What experiences do you have with income-generating use of **SSHS**?

Potential and constraints for productive use of SHS

11. In communities without any electricity supply, what are the **most common productive / income-generating activities** found on household, agriculture and small business level? (distinction by area)
12. Could any of these processes be **improved by the use of solar electricity**? If yes: give examples!
13. Do you know of previous / current experiences / initiatives regarding the **promotion of productive devices** for SHS?
14. What are the major **constraints / barriers** for the widespread use of SHS for income generation?
15. How could these constraints be **overcome**? What needs to be done for a more widespread use of SHS for income generation?
16. Are people that already own a SHS (**families with high income**) have motivation to use evening lighting for productive purposes / purchase additional productive appliances?
17. Do you have concrete plans to promote the productive use of SHS through your organisation in the future?

Solar water pumping
18. What experiences does your organisation have with solar water pumping / irrigation? Do you know of pilot projects / initiatives of other organisations?
19. What are current constraints to promote the use of solar technology for irrigation?
20. How could these constraints be overcome? What needs to be done for a more widespread use of solar technology for water pumping?

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