MSc Program
Renewable Energy in Central and Eastern Europe

Rural EmPOWERment, Electricity Generation by Renewables and application of Microfinance for Sustainable Development – An investigation of Grameen Shakti and Bangladesh

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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Affidavit

I, Mag. Jacqueline Posch, hereby declare

1. that I am the sole author of the present Master Thesis,

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   153 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
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Abstract

While a considerable increase in wealth can be observed in certain parts of the world, an enormous number of people are still struggling every day to survive. The provision of electricity by renewable energy (REN) to everybody could not only tackle the poverty issue and lead to economic, health and social benefits, but also would have a very positive influence on the environment and hence could guarantee a sustainable way of living. How this could be undertaken will be presented in this paper. As field of study Bangladesh, one of the most populated and poorest countries worldwide, has been chosen. Therewith the company Grameen Shakti (affiliate of the famous microfinance institution Grameen Bank) which is successfully promoting REN technologies in Bangladesh is highlighted. Information provided in this paper has been derived from subject-specific literature, internet research and from a field study trip to Bangladesh undertaken by the author in February and March 2013.

The purpose of this paper is to introduce microfinance and to discuss its potential as financing option for REN. The importance of access to energy for people in developing countries and related REN technology options (also including hybrid solutions and mini-grid aspects) are presented. Therewith also the relevance of the productive use of REN is discussed. Bangladesh's energy situation as well as its REN possibilities, also by studying the technical potential of various REN technologies in a specific chapter, are reviewed. Moreover, the renowned Grameen Bank and Grameen Shakti (GS) are presented. Key success factors for sustainably promoting REN in developing countries by help of microfinance are derived and advantages of use of REN technologies are presented. According to the findings of the REN potential in Bangladesh one technology, namely rice husk gasification, which is not yet applied by GS but deemed to be viable, is reviewed from an economic point of view, which shows that under certain pre-conditions this technology can be feasibly deployed. Further, a community REN model based on microfinance, which has been created by the author of the paper as option to spur development, is introduced. Finally, the replicability of the GS experience in other countries is assessed.

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List of abbreviations

AC	Alternating Current
ADB	Asian Development Bank
APSCL	Ashuganj Power Station Company Ltd
BERC	Bangladesh Energy Research Council
BIMSTEC	Bay of Bengal Initiative for Multisectoral Technical and Economic Cooperation
BOO	Build Operate Own
BOS	Balance of System
BOT	Build Operate Transfer
BPDB	Bangladesh Power Development Board
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CFL	Compact Fluorescent Lamp
Co-op	Co-operative
CSR	Climatological Solar Radiation
DC	Direct Current
DEPL	Dreams Electrification Project Pvt Ltd
DESA	Dhaka Electric Supply Association
DESCO	Dhaka Electric Supply Company
DGIS	Ministry of Foreign Affairs of the Netherlands
DLR	German Aerospace Centre
EDI	Energy Development Index
EGCB	Electricity Generation Company of Bangladesh
EPC	Engineering, Procurement, Construction
FAO	Food and Agriculture Organization
GB	Grameen Bank
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Green House Gases
GHI	Global Horizontal Irradiance
GPOBA	Global Partnership on Output-Based Aid
GS	Grameen Shakti
GSBP	Global Social Business Partners
GSSB	GS Social Business

GTC	Grameen Technology Center
GTZ	(German) Society for Technical Cooperation
HDI	Human Development Index
ICS	Improved Cooking Stove
IDA	International Development Agency
IDB	Islamic Development Bank
IDCOL	Infrastructure Development Company Limited
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IFC	International Finance Corporation
IFI	International Financial Institution
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
KAMM	Karlsruhe Atmospheric Meso-scale model
KfW	German Development Bank
LED	Light-Emitting Diodes
LGED	Local Government Engineering Department
MB	Microcredit Bank
MDGs	Millennium Dev.Goals
MF	Microfinance
MFI	Microfinance Institution
NGO	Non-governmental Organization
NWPGCL	North West Power Generation Company Ltd
O&M	Operation and Maintenance
PGCB	Power Grid Company of Bangladesh
PGEL	PUROBI Green Energy Ltd
PO	Partner Organization
PV	Photovoltaic
R&D	Research and Development
RBF	Rockefeller Brothers Fund
REB	Rural Electrification Board
REN	Renewable Energy
RERC	Renewable Energy Research Centre
RERED	Renewable Energy for Rural Economic Development

SAARC	South Asian Association for Regional Cooperation
SEAL	Sustainable Energy & Agro-resource Ltd
SHPP	Small Hydro Power Plant
SHS	Solar Home System
SNV	Netherland Development Organisation
SREDA	Sustainable & Renewable Energy Development Authority
TUV	International Certification Organization
UN	United Nations
UNCDF	UN Capital Development Fund
UNDP	UN Development Programme
UNEP	UN Environment Programme
UNFCCC	UN Framework Convention on Climate Change
UNIDO	UN Industrial Development Organization
US	United States
USAID	US Development Agency
WACC	Weighted Average Cost of Capital
WAsP	Wind Atlas Analysis and Application Program
WZPDCL	West Zone Power Distribution Company Ltd
WZPDCO	West Zone Power Development Company

1 Introduction

1.1 Motivation

Considering nowadays threats due to climate change, challenges related to steadily increasing population rates and persistent high levels of poverty, an adequate management of available resources and effective support for sustainable development seems to be indispensable. One major issue therewith is access to "green" energy. About 1.4 bn people are still without electricity today and outlooks show an increase in world's population growth of about 2 billion until 2050 (mainly concerning developing countries), which will further increase energy demand (Nakicenovic et al. 2012).

The United Nations (UN) agreed on the following eight Millennium Development Goals (MDGs) in 2000[23]:

1. Eradicating extreme poverty and hunger,
2. Achieving universal primary education,
3. Promoting gender equality and empowering women,
4. Reducing child mortality rates,
5. Improving maternal health,
6. Combating HIV/AIDS, malaria, and other diseases,
7. Ensuring environmental sustainability, and
8. Developing a global partnership for development

As energy is deemed to be crucial for sustainable development and poverty reduction by affecting social, economic and environmental aspects the UN started the "**Sustainable energy for all"** initiative. It is assumed that the MDGs cannot be achieved without securing clean, reliable and affordable energy services in developing countries.

Providing electricity to energy starving regions entails lots of benefits. Studying and working hours can be increased, irrigation pumps and refrigerators can be used and time on gathering fuel wood, etc. can be saved. All this can lead to an increase in income and also to improved purchasing power. The promotion of electricity supply

[23] http://www.un.org/millenniumgoals/

itself can also create jobs in the technology related production and distribution sector.[24] Hence, the need for rural electrification becomes clearly evident.

In order to combat climate change, to secure healthier living conditions for people and to lower energy imports renewable energy (REN) generated by sun, wind, water, biomass and geothermal resources shall be focused. Such technologies are becoming cost-competitive due to increased use.[25]

Therefore, with providing electricity on REN basis to rural areas in developing countries, living conditions (including health, education, employment, etc.) for locals can be improved considerably, the environment can be preserved and sustainable development can be achieved.

Vast areas of developing countries are off-grid and due to remoteness of villages, scattered locations, insufficient load demand, missing financial feasibility and restrictive resources for infrastructure the grid expansion in those locations is not to be expected to be followed up soon. REN would be an option to electrify those areas either as household or as mini-grid solution providing whole communities with electricity. There are plenty of technologies available which could be used for this purpose. However, adequate funds have to be secured to afford REN applications (Bhowmik n.a.).

Poor people often lack capital to invest into electricity generating technologies. Microcredit can play a significant role in countering this deficiency. It is a credit scheme for low-income households providing affordable loans to ideally finance income-producing activities. The principle of microcredit is described in chapter 2.1 of the paper. Effective credit programs in place to promote REN are very important to spur sustainable development (Allerdice and Rogers 2000).

Hence, this paper will focus on promotion of REN for the rural population of developing countries by funding through microcredit.

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[24] http://www.sustainableenergyforall.org/objectives/universal-access
[25] http://www.sustainableenergyforall.org/objectives/renewable-energy

As place of study **Bangladesh** has been chosen for this paper. The UN by application of the Human Development Index (HDI), which measures the well-being of a countries population by considering health, education and income, has ranked Bangladesh low at number 146 out of 187 countries in 2011.[26] Further, in 2010 Bangladesh showed a very high population density of 1,142 people per km² land area in comparison to eg 34 inhabitants per km² in the US or 102 people per km² in Austria.[27] By that time 45% of Bangladesh's population earned less than 1.25 USD per day.[28] It seems to be indispensible to secure adequate energy services for densely populated Bangladesh with a high poverty level to facilitate proper health, education and employment opportunities. This could lead to empowerment of the people and sustainable development (Rahman 2012).

In Bangladesh, with a population of 161 million people (2012 est.) only about 50% are provided with electricity in total[29]. Each inhabitant consumes on average 279 kWh (2010)[30] only. In contrast, per capita electricity consumption eg in the US was 13,394 kWh and 8,356 kWh in Austria in 2010 and in other developing countries like eg Thailand it reached about 2,243 kWh per capita in 2010.[31] In addition, the country is confronted with frequent power blackouts (Weimar 2010). The majority of the electricity generation in Bangladesh has so far been derived from natural gas. Forecasts show that the indigenous gas will be depleted by 2030. The Bangladesh government is following a vision of electricity for all and therewith aims at promoting REN (Sharif/IDCOL 2009). However, lack of relevant data, R&D and of expertise on system design, installation and O&M are hindering the facilitation of REN technologies in Bangladesh (Rahman 2012). Moreover, the Bangladesh government is not deemed to widely extend the national grid soon as the rural poor are scattered and often cannot afford the electricity price of about 5 Tk / kWh (Weimar 2010).

The above given shows that Bangladesh does not have abundant power plants and extensive grids available which could ensure secured electricity supply.

[26] http://hdrstats.undp.org/en/countries/profiles/BGD.html
[27] http://data.worldbank.org/indicator/EN.POP.DNST/countries?display=default
[28] http://data.worldbank.org/indicator/SI.POV.DDAY
[29] http://www.powerdivision.gov.bd/user/brec1/30/1
[30] measured by the production of power plants less transmission, distribution and transformation losses and own use by power plants
[31] http://data.worldbank.org/indicator/EG.USE.ELEC.KH.PC

Decentralized solutions such as REN for electricity provision could close this gap and are urgently needed.

Being amongst the most populated and poorest countries worldwide and heavily lacking adequate electricity supply, this nation seems to be very well suited as country of research.

Bangladesh has also been chosen as country for research as the mother of microfinance "Grameen Bank" and its affiliate "Grameen Shakti" (GS), which focuses on REN promotion, are located there. Grameen Bank was founded in Bangladesh in the early eighties and has later on established GS, which is selling mainly PV and also biogas plants and improved cooking stoves on credit to the rural poor. Grameen Shakti means village energy. It was founded in 1996 and is meanwhile the largest off-grid rural solar energy provider in the world.[32]

1.2 Core objective

Given the above it becomes evident that research in the field of REN applications for rural areas of developing countries and microfinance funding is important. There is plenty of literature available in general on microfinance, but not many books on microfinance funding for REN applications have been published so far. GS as an affiliate of one of the most recognized MFIs worldwide, namely Grameen Bank, seems to promote REN installations in rural Bangladesh very well. However, not many papers can be found on their business. Hence, this work is aiming at closing this gap. GS itself is selling REN equipment on credit to the rural poor in Bangladesh. It is not considered to be a MFI, but it is catering the rural poor and it is deemed to have strong ties with Grameen Bank.

Especially, foundations of **microenterprises** supported by access to REN, which can be adequately funded by microcredit, are deemed to lead to sustainable development. Hence, models and examples confirming this connection shall be more deeply examined.

Further the paper aims at presenting small-medium scale **REN technologies**, which are deemed to be adequate for application in rural areas of developing countries.

[32] www.gshakti.org

Dependent on local specific characteristics different REN technologies can be chosen and deployed.

As stated above, the company **GS** shall be investigated as it is assumed that this company very well follows a successful model for REN promotion in rural Bangladesh. By using the experience gathered by GS as basis, conclusions on the suitability and viability of microfinance for REN promotion and consequently rural development will be drawn. There have also been counter arguments against microfinance as successful tool for poverty alleviation. Therefore, by studying the GS model and also by reviewing lessons learnt by MFIs, this paper shall show which are the key factors which shall be respected in order to apply the microfinance plus REN model feasible and sustainable, for the borrowers as well as for the financial institutions respectively equipment suppliers.

So far the main focus of GS has been on Solar Home Systems (SHS) but also on biogas since 2005. The aim of this paper is to study which other **technologies** (such as biomass gasification, wind, hydro) are feasible in the context of **Bangladesh** dependent on local special characteristics.

Moreover, this paper shall investigate whether **community REN models**, which could provide electricity to whole communities via mini-grids, are feasible for rural Bangladesh and could be properly funded by microfinance. The idea is to provide microfinance to plenty members of a community to derive necessary funds for REN projects. Making microfinance available for such community REN models could also positively affect the promotion of community services, such as schools, clinics, etc., which will be shown in the empirical part of the paper. Hence, this research shall conclude whether other REN technologies than SHS or small scale biogas shall be addressed by GS in the future and whether community REN models shall also be applied in order to boost REN installations in rural areas.

Finally the **replication potential** of the GS model shall be discussed. Presumably there is a lack of awareness of options for rural electrification and development, which can be encountered herewith.

The following research questions shall be tackled:

- **By taking the GS experience into account, A) which are the key success factors for sustainably promoting REN in rural areas of developing countries with help of microfinance and B) which advantages can be encountered by use of GS REN technologies?**
- **Which REN technologies could be applied in Bangladesh from a technical and (if technically feasible) also from an economic point of view and may be provided by GS in the future?**
- **Should community REN models based on microfinance be pursuit in order to spur economic and social development?**
- **Is the GS approach replicable in other countries?**

1.3 Method of approach

In order to generate relevant data, subject-specific literature, journal and internet research has been undertaken. Therewith information has also been derived from international organizations, such as UN, as well as local authorities. In addition a field study trip to Bangladesh (February/March 2013) has been conducted. Thereby Grameen bank has been visited and Grameen Shakti has been studied in detail by inter alia inspecting executed projects and by carrying out interviews with Grameen staff at headquarters and at the field level as well as with various clients and also non-customers.

Different households in Sunamgonj (Sylhet division) and Shariatpur (Dhaka division) have been asked regarding REN systems (most of the GS clients interviewed own SHS). An open questionnaire serving as guideline for the interviews has been developed (Annex 1). Due to the purpose, local culture, educational background and social system established a different interview approach would not have been feasible. Findings can be found in different parts of chapter 3.2 and have been marked accordingly.

1.4 Structure

As already pointed out above, this paper focuses on microfinance and REN for developing countries. First theory will be studied and afterwards empirical research will be undertaken.

In the first part of the paper the idea of **microfinance** for developing countries will be presented. The historical background, principles, special characteristics of the microfinance sector, lessons learnt as well as opportunities concerning REN will be reviewed. Afterwards the need of and possibilities for **REN in developing countries** will be studied. Therewith underlying challenges and technology options will be presented.

In the empirical part, an overview over the country of research, **Bangladesh**, will be provided. After informing about the country's history, general data as well as details about the power sector will be given. Then **GS** will be presented. The company's development as well as its success factors will be introduced. Positive aspects of REN promotion in rural areas will be assessed, such as provision of productive jobs, by screening the GS approach. Afterwards it will be investigated which **REN** technologies could be applied in principal in **Bangladesh**, dependent on local specific characteristics. This shall provide ideas for further REN perspectives for GS. Thereafter it will be studied whether the microfinance for **REN** promotion principle is also feasible on extended **community** base (via a community REN model) in order to make larger REN projects (including mini-grids) financially sound and hence to provide further positive economic, environmental, human and social impact. Finally, the paper will draw a conclusion and examine whether the **GS model** is deemed to be **replicable** also in other developing countries.

2 Part I – Literature review

2.1 Microfinance in Developing Countries

2.1.1 History

Poor people in developing countries are facing difficulties as credit markets are underdeveloped, property rights are not properly defined and legal systems are unreliable and costly. Formal sector banks serve only few poor people, as the poor are perceived as being unreliable without collateral and the often highly bureaucratic institutional procedures of commercial banks are incompatible with the poor. Alternatively poor people lacking funds can address the informal money lending sector. However, those lenders are usually demanding extremely high interest rates. In order to tackle this credit problem by offering inexpensive credit to the rural poor microfinance has been set up in the mid of the 20th century. Aid organizations started funding rural credit programs by providing money to central banks and agricultural banks (Jaffer 1999).

Research shows that the vision of bringing financial services to the poor follows a long history. Eg already in the 1800s Wilhelm Raiffeisen developed the model of financial cooperatives. “Microcredit” as it is known today was born in the 1970s with Prof. Muhammad Yunus, who founded the Grameen Bank, being a pioneer in the field (Helms 2006).

The nobel laureate Muhammad Yunus said that the market theory where all people are employed, have access to credit and stay in equilibrium could not be confirmed by the situation of the poor. Poor people aiming at starting small businesses could not progress as formal lenders refused loans due to lack of collateral and informal lenders were charging exorbitant interest rates. This problem had to be tackled and thus microfinance has been borne (Yunus and Jolis 2003).

2.1.2 Underlying economics, Human and Social capital

The idea of microfinance can be based on the theorem of efficient allocation of resources. Some people with spare money are looking for investment possibilities and others face business opportunities but are lacking financial means. Connecting those parties sounds reasonable, however it has to be considered that economic opportunities for the poor are not indefinite and adequate demand for new products has to be secured. Further, when somebody is taking out a loan to promote a new business, the person might experience high returns at the beginning but this step might entail increased competition in a region and prices for end-products will decrease whereas costs of raw material will increase leading to less profits in the long-run. For being sustainable the new entrepreneur has to secure ongoing adequate profits to cover interest rates and earn a living. It shall also be taken into account that new entrepreneurs may affect already existent sellers, who then in return might lose market share, have to reduce prices, etc. and in this regard poverty levels might increase again. Moreover, other market customers may also pursue a loan in order to afford new products having been made available by a new entrepreneur. The therewith related increase in demand will lead to higher product prices which will in return lead to less affordable quantities and market customers will also have to service their loans. Markets will reach new equilibrium and hence long-term benefits for loan takers have to be assessed (Sinclair 2012).

As stated above various economic aspects have to be considered when thinking of sustainable microfinance. However, when applied properly, microfinance can have very positive impacts on economic, human and social variables, which is shown in the following figure (Wrenn 2005).

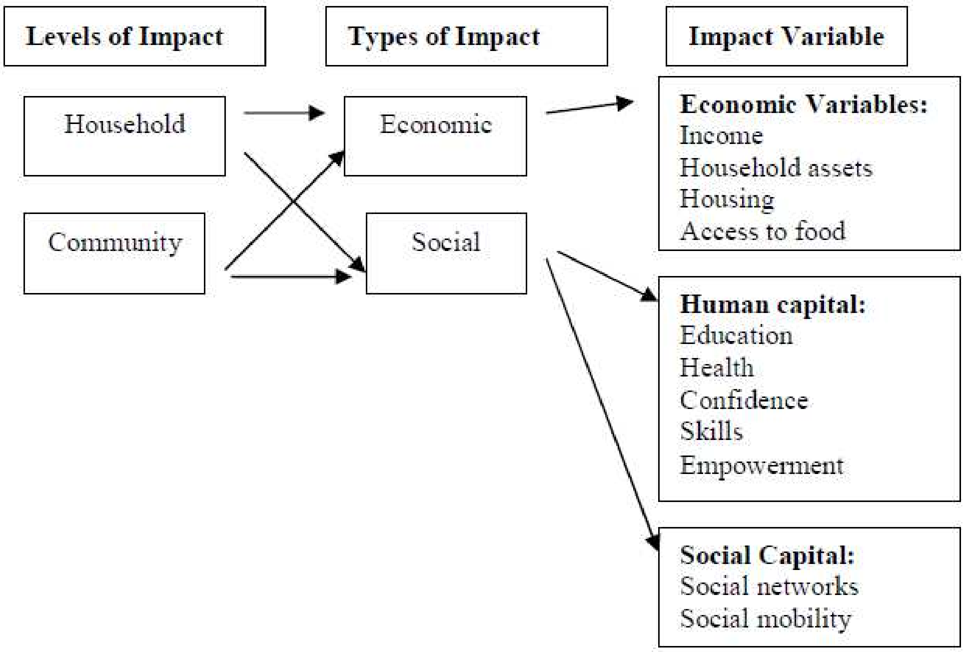

Figure 1: Potential impact of MF at a household and community level (Wrenn 2005)

2.1.3 Fundamental principle

The fundamental principle on which microfinance has been based on is **joint liability**, which could be explicit or implicit. **Explicit** in this sense means that borrowers form groups and in case one is unable to repay the loan other group members have to pay instead as per contract. They will usually be motivated to repay the loan, as otherwise they would not be able to benefit from future credits. Another option for the bank would be to use a group savings fund which is established for the purpose of serving as collateral. **Implicit** joint liability in contrast means that the borrowers think that if one of the group members defaults then every member of the group will lose access to future loans, even if this is not specified in the loan contract. As community members amongst each other usually have more information than banks would have and further can use powerful non-financial sanctions against each other microfinance based on a joint liability mechanism has proven to be very successful for poor people lacking adequate collateral (Fischer and Ghatak 2011).

In addition **frequent repayment** and **sequential lending** has been set up in order to guarantee effective microfinance and also to arrange for **individual liability loan** solutions. A loan with frequent installments is beneficial as poor people would otherwise be overwhelmed by large payments. The advantage of sequential lending is that borrowers do not receive loans at once, but only after eg one member has already paid some installments. Therefore group members will scrutinize the others payment behaviors (Fischer and Ghatak 2011).

Loan terms are usually three months to two years and repayment is scheduled on a regular scale in small amounts, often weekly as this is securing disciplined clients (Morduch 1999). Some credit schemes include a grace period, during which no repayment is demanded however interest will be charged. The scheduled time of repayment can also be linked to the harvesting cycle, etc. in order to observe the borrower’s ability to pay back a loan. Usually field officers visit one member to disburse respectively collect loans in case of group lending as travelling is expensive (Sinclair 2012).

Microfinance Institutions (MFIs) also capture savings from borrowers upfront to be used as collateral and hence called forced savings. This reduces the risk for MFIs for non-payment (Morduch 1999). However, MFIs shall not use such savings to on-lend them to other customers or to cover own operating costs. Another collateral option is to confiscate goods which are bought by loan-takers in case of default (Sinclair 2012).

2.1.4 Microfinance products

Microfinance comprises the provision of loans, deposits, payment services and insurance to poor people. Borrowers are deemed to be given the opportunity to lift themselves out of poverty by provision of adequate financial services.[33] This paper focuses on micro-loans/microcredit. As it will be shown later in the paper, poor people can already achieve considerable progress when they are granted tiny credits.

By the help of microcredit micro-enterprises can be fostered and hence poor people can escape poverty. Employment can be created and income increased, which can further lead to higher children's education, improved health and women empowerment (Soumitra and Samirendra 2011).

2.1.5 Interest rates

The interest rates charged by MFIs are considerably higher than in case of standard commercial banks as operating costs are very high due to a high number of staff, which is needed to serve many poor also in remote areas and because of a large amount of loans which has to be processed. However, interest rates of MFIs are attractive to the poor as they offer a loan opportunity often much cheaper than in the case of lending from the informal market. Moreover, informal money lenders usually use a flat rate basis when calculating interest rates, which means that they charge interest on the total original loan balance. In contrast banks compute effective interest rates on the outstanding loan balance (Hulme and Arun 2009).

2.1.6 Microfinance Institutions (MFIs), funds and investors

Formal institutions, like rural banks, semiformal institutions, like non-governmental organizations, as well as informal sources, like money lenders, provide microfinance services. MFIs include formal and semiformal institutions, whose main business is the provision of microfinance services.[34]

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[33] http://www.adb.org/sectors/finance/microfinance
[34] http://www.adb.org/sectors/finance/microfinance

MFIs are usually established as not-for-profit organizations, which receive money from aid agencies. They benefit from low tax and are expected to re-invest generated profit. However, it shall be guaranteed that money is not diverted from promoting the poor by being used for very high salaries, cars, etc. MFIs can also transform to become a for-profit organization and attract shareholders (Sinclair 2012).

Investors, such as multilateral organizations, governments, pension funds and savings funds or well-off individuals, can provide money via funds to MFIs, who then distribute it to the poor people via loans. Loans have to be priced properly to cover operating costs, non-repaying clients, etc. Some of the funds not only lend money to MFIs but they also invest into equity, which entails higher risk but can lead to increased profit. In such case they have to think of how much shares are worth and have to forecast a MFIs growth and their possibilities to sell shares again. MFIs pay a management fee between usually 1 to 4% to the funds in order to cover their operating expenses, such as staff, offices, flights, due diligences, etc. Funds are confronted with high fixed costs and therefore try to reach very large scales. MFIs can sometimes also profit from voluntary savings, however in such case strict rules have to be followed in order not to on-lend too much and on risky base which would lead to a MFI collapse. The goal of a MFI should be to become self-sufficient with the main objective to alleviate poverty and to foster development by promoting self-employment, providing assistance, respecting cultures and human rights (Sinclair 2012).

2.1.7 Microfinance and women

MFIs often favor providing loans to women as experience shows that they are showing higher re-payment rates due to different factors. One is that they often do not have alternative credit sources and hence are motivated to re-pay a loan to secure future loan access. Another is that women are deemed to be more sensible to verbal motivation of group members or bank staff and do not as much counter-argument as men. They can also be easier addressed by bank employees as women usually stay closer to their homes than men. Besides higher re-payment rates which are favorable for MFIs, lending to women also brings other advantages. For example, women tend to be more social and family concerned than men and hence will utilize loans to improve children’s health, education, etc. Moreover, women are often oppressed and can use loans to generate and control their own income and can empower themselves (Amendáriz and Morduch 2005).

2.1.8 Rating agencies

For analyzing and monitoring MFIs there are some rating agencies available, such as Planet Rating or MicroRate, which review MFIs and perform on-site analysis and desk research by using standardized templates. The produced rating reports offer some transparency to the microfinance sector.[35]

2.1.9 Mix Market

In order to access objective performance data of different MFIs and related funds and to make the sector more transparent also the “Microfinance Information Exchange” (MIX Market) can be used. Mix Market was founded in 2002 as non-profit organization and is placed in Washington DC. Financial and social performance data, such as financial statements, client outreach, etc. of about 2,000 MFIs worldwide are available online on this platform.[36]

The Mix Market offers transparency to the sector by providing various financial indicators, eg.:

- **Loan Loss Rate**
  “(Write-offs - Value of Loans Recovered)/ Loan Portfolio, gross, average”
- **Portfolio at Risk > 30 days Ratio (%)**
  “Portfolio at Risk > 30 days/ Loan Portfolio, gross”
- **Cost per Borrower**
  “Operating Expense/ Number of Active Borrowers, average”[37]

Mix Market provides information on Grameen Bank, but not on Grameen Shakti. As mentioned, Grameen Shakti is not a MFI. Hence, this platform will not be used in this paper however it, as well as the rating agencies stated above, are deemed to be worth mentioning as they may delivery valuable insights when assessing MFIs in various developing countries which could include REN into their portfolio and therewith promote REN dissemination.

2.1.10 Lessons learnt

In principle, during the past decades the concept of microfinance as tool for poverty reduction found widespread approval. However, also concerns have been raised in regard to the effectiveness of microfinance programs. Some argued that they should

[35] http://www.planetrating.com/EN/index.php and http://www.microrate.com/
[36] http://www.mixmarket.org/about
[37] http://www.mixmarket.org/about/faqs/glossary

be more qualitative in order to really achieve the maximum development effect. A well-defined strategy is apparently necessary for conducting microfinance programs effectively (ADB 2000). The following paragraphs provide lessons learnt and show which aspects have to be considered in order to provide an effective tool for poverty alleviation.

Muhammad Yunus once said: *"I never imagined that one day microcredit would give rise to its own breed of loan sharks"* and *"You will never see the situation of poor people if you look at it through the glasses of profit-making".* This very well describes the problems which arose in the microfinance sector. Many MFIs and underlying funds followed inefficient inadequate approaches and hence deprived the poor of chances. However, as Hugh Sinclair says in his book:"*Microfinance with a soul does exist, but only if the investors and regulators want it to exist"*, and *"Microfinance is possible to be efficient, profitable and ethical while offering reasonably priced loans"* (Sinclair 2012). In order to guarantee a proper approach the following shall be observed:

As there is a principal-agent problem between **investors** and funds, investors shall scrutinize funds to make sure that they do follow adequate procedures and not only aim at enriching themselves. Due diligence and also field trips to properly analyze and monitor MFIs shall be undertaken by funds. Investors shall read rating reports, review websites and attend annual general meetings of funds. Hard facts, such as adequate interest rates, proportion of consumption versus production loans, etc. shall be investigated (Sinclair 2012).

Concerning **funds** a qualified formal regulation has to be secured like in any other commercial investment sector. Adequate management fees shall be charged to cover proper due diligence and on-site monitoring and to employ experts. They shall read MFI ratings respectively employ rating agencies to undertake ratings if none are available. They shall not just follow other funds in a herd instinct. Funds shall publish investments and actual interest rates. Sometimes they focus on the barometer "credit access", which is not considering interest rates charged. Many borrowers may be registered, however many of them may face severe problems of re-payment due to exorbitantly high interest rates, they may take out new loans just for being able to pay back other loans and hence, the purpose of sustainable development becomes questionable. Funds shall not be looking for the highest possible returns, but shall be ready to correct mistakes not only when being confronted with reputational damage and they shall respect objectives of investors (Sinclair 2012).

MFIs shall review clients and assess their capacity for re-payment. Loans shall be tailor-made and shall also include training for the clients. MFIs shall focus much more on production than on consumption loans as they are more sustainable. They shall prevent over-indebtedness of customers, shall not pursue aggressive growth, but shall keep borrowers desertion rate low and shall underlay strict regulations. MFIs shall stick to Generally Accepted Accounting Principles. Interest rates have to be calculated right, by considering correct loan periods, loan sums, decreasing interest base (in contrast to flat rates), etc. Interest rates as well as other charges, commissions and forced savings shall be kept at a reasonable level. MFIs shall use well-functioning IT systems, which can save money and time and can deliver accurate data. In general, MFIs shall visit clients regularly and shall ensure abundant and correct data. Main facts shall also be publicly reported by them. Further MFIs shall employ experienced staff with clear function without affinity to bribery and shall show high productivity and efficiency. MFIs shall also pick funds carefully and keep close contact with them. Looking only at growth of loan portfolios, coverage of operating costs and generation of profits is insufficient to secure sustainable development of their clients (Sinclair 2012).

Borrowers shall review whether they really need a loan and make sure that their intended business will be able to generate sufficient profit in order for being able to repay loans and to pay interest rates and other related arising costs. Poor people shall not take out consumption loans and shall not take out loans to pay another as this is not sustainable. Borrowers shall inform regulators respectively local press if they are treated badly. Cases have been reported in which borrowers committed suicide, child labor has been involved, etc. due to improper treatment of borrowers. They shall benefit from training provided by MFIs and shall become self-sufficient (Sinclair 2012).

As self-regulation is deemed to be an oxymoron, adequate **regulation** in the microfinance sector has to be secured. Existent regulatory authorities are often badly equipped and funds resist to regulation and do not properly control MFIs. This has to be changed. For example, maximum applicable interest rates and other charges shall be set. Debt collection practices shall be monitored, etc (Sinclair 2012).

Grameen Shakti, which is investigated later in this paper, has proven to charge adequate interest rates and to promote rural development in a sustainable way.

2.1.11 Present Opportunities for Microfinance and REN

Poor people live in subsistence economies, often receive irregular income if any, frequently do not generate cash surpluses and also face restricted access to credit. Hence, they lack funds to afford improved energy supplies which often entail high up-front costs and also cannot afford energy conversion technologies (such as light bulbs, radios, etc.) even if they could be supplied in their vicinity. Therefore, they do not have electricity available to power machines which leads to low productivity and this in return reveals only little cash to afford a living. Thus, poor people are said to be trapped in a vicious cycle of energy poverty (UNIDO/REEEP 2005). The International Energy Agency (IEA) defines **energy poverty** as "*A lack of access to modern energy services. These services are defined as household access to electricity and clean cooking facilities (e.g. fuels and stoves that do not cause air pollution in houses)*."[38]

When poor people achieve to buy improved energy technologies and hence experience savings as they do not have to buy candles, etc. anymore they still may face increased expenditures as they make more use of the improved energy services. To overcome this issue and to **break the vicious cycle of energy poverty**, poor people should use increased access to energy to promote profitable productive enterprises. This idea is shown in the below given figure. Access to energy can increase productivity, enlarge outputs and improve quality. This is deemed to be more sustainable than just providing grants and subsidies from governments and NGOs as such are faced with limited funds. After income generating enterprises have been established also further important social aspects, like clinics or schools can be focused (UNIDO/REEEP 2005).

[38] http://www.iea.org/topics/energypoverty/

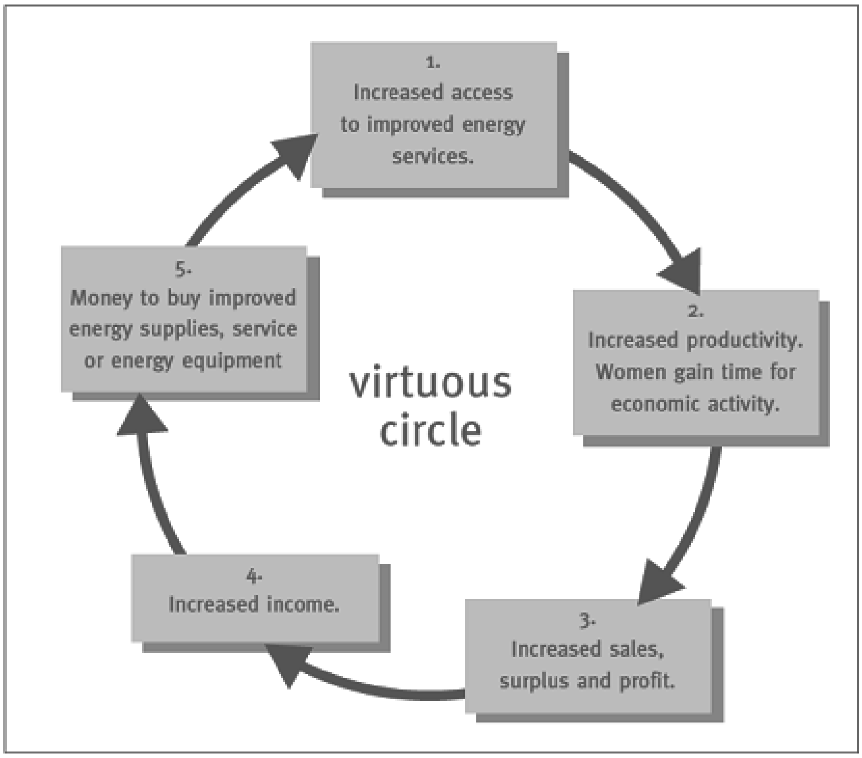

Figure 2: A virtuous circle to break out of energy poverty (UNIDO/REEEP 2005)

Dependent on the definition **productive use of energy** may only be directly related to income generating activities or it can also relate to eg improved education and health, which can indirectly lead to higher productivity and development. Eg Kapadia 2004 defines productive use of energy broadly 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 contrast according to White 2003, a productive use of energy is defined narrower 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".*

As described in the narrower definition, when thinking of poverty alleviation microenterprises, which are very small businesses, can play a key role to create jobs and hence generate income. Access to electricity can entail significant advantage for those microenterprises by making them more productive. Use of REN is very favorable in this regard as it not only entails environmental benefits but also offers adequate access to energy to the poor, who are often without access to the national grid. However, micro-entrepreneurs very often lack financial resources to afford electricity respectively devices for power generation. Options for closing this gap have to be found (Allerdice and Rogers 2000).

REN technologies can in principle be financed through dealer sales, credit through commercial banks or MFIs, or fee-for-service models, in which the service provider stays to be the owner of equipment. REN technology sellers respectively dealers sometimes provide equipment on credit to be repaid over 3 to 12 months. Further, local commercial banks directly (eg in Kenya) or via MFIs (eg in Sri Lanka) can provide loans to afford REN technologies. In some cases International Financial Institutions (IFIs) offer support (eg in Bangladesh, India or Nepal). Prior service agreements for repair and maintenance, etc. between financial institutions and REN suppliers can be established to ensure success and loans can be tied to certain qualitative suppliers. In case of the fee-for-service model clients pay to receive energy from an energy service company, which keeps ownership and is responsible for maintenance. Governments are often financially supporting such schemes and can ensure standards and quality control. MFIs sometimes provide very short-term loans to make the above stated fees affordable. Loans from commercial banks are not suitable for the purpose discussed in this paper as such are usually designed to address high and middle-income customers but not the poor, which show lack of collateral and entail high transaction costs due to the small loan amounts they could afford and their often remote living places. Financing by MFIs seems to be a viable option and has already been proven to be successful in different cases. Usually clients take loans of about 50% to 100% of the REN technology costs. First such projects have been pursued in Nepal with household biogas and in Nepal and Sri Lanka with home PV systems followed by Bangladesh, Kenya and Tanzania (UNDP and UNCDF 2012).

As MFIs often feature extensive well established rural networks they can be very supportive in promoting new electricity generating technologies. The following figure depicts the promising connection of microfinance, microenterprise and REN (Allerdice and Rogers 2000).

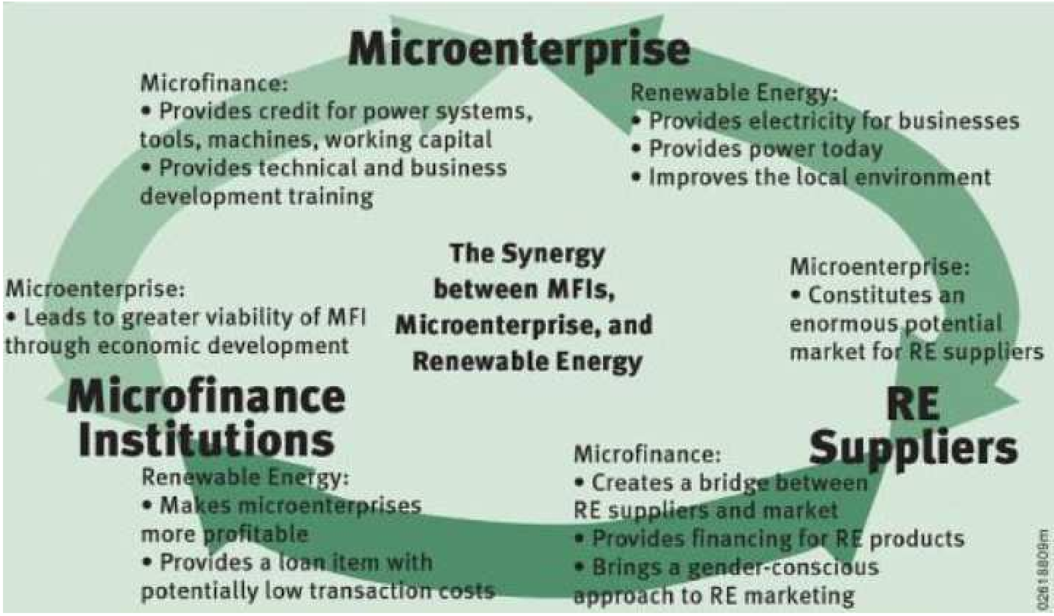

Figure 3: Interdep. of MF, microenterprise and REN (Allerdice and Rogers 2000)

The great achievements by MFIs and their relationships built up with low-income customers in the past can be used very effectively to address problems such as energy poverty and climate change. MFIs can promote high-impact products such as REN now and in the future to counteract those challenges. Prices for REN technologies are decreasing and hence MFIs can make such technical solutions available and affordable to the poor and can promote micro-enterprises (Counts et al. 2011).

The **CleanStart** program established under the "**Sustainable energy for all**" initiative of the UN, which has already been mentioned in the introduction of this paper, formulated an attractive business model considering microfinance for funding of REN. The UN initiative follows three goals, namely to ensure universal access to modern energy services, to double the rate of improvement in energy efficiency and to double the share of REN in the global energy mix by 2030. The CleanStart program therefore created a business model to promote REN in developing countries, which is depicted in the below given figure. The program intends to assist a minimum of 2.5 million people in Asia and Africa to escape energy poverty by 2017. As adequate financial means are necessary to make REN accessible to the rural poor micro-financial services came into focus. Appropriate technical assistance, knowledge dissipation, advocacy and partnership in this sector have been assessed as further essential components for successful REN promotion. Various stakeholders, such as technology end-users, supplying retailers and maintenance staff, policy makers and financial institutions shall be involved in a holistic approach for long-term success (UNDP and UNCDF 2012).

MFIs can be supported by CleanStart through pre-investment technical assistance (to raise awareness and to develop business plans), risk capital grants (to meet up-front costs of new product lines) and concessional loans (to help MFIs to scale up their lending and become self-sustainable). At the beginning MFIs might not have proper funds at hand for clean energy products as their lenders perceive such products as risky. Proceeding demonstrations in this sector shall prove to the contrary and make credit lines available. It is important that MFIs as well as their customers understand the financial respectively technical risks involved with clean energy products. MFIs shall assess their clients' current energy costs and their willingness and ability to pay for clean energy. Further MFIs shall set up co-operations with energy system suppliers, address technological/service gaps in the supply chain, if any, and shall develop proper financing products (UNDP and UNCDF 2012).

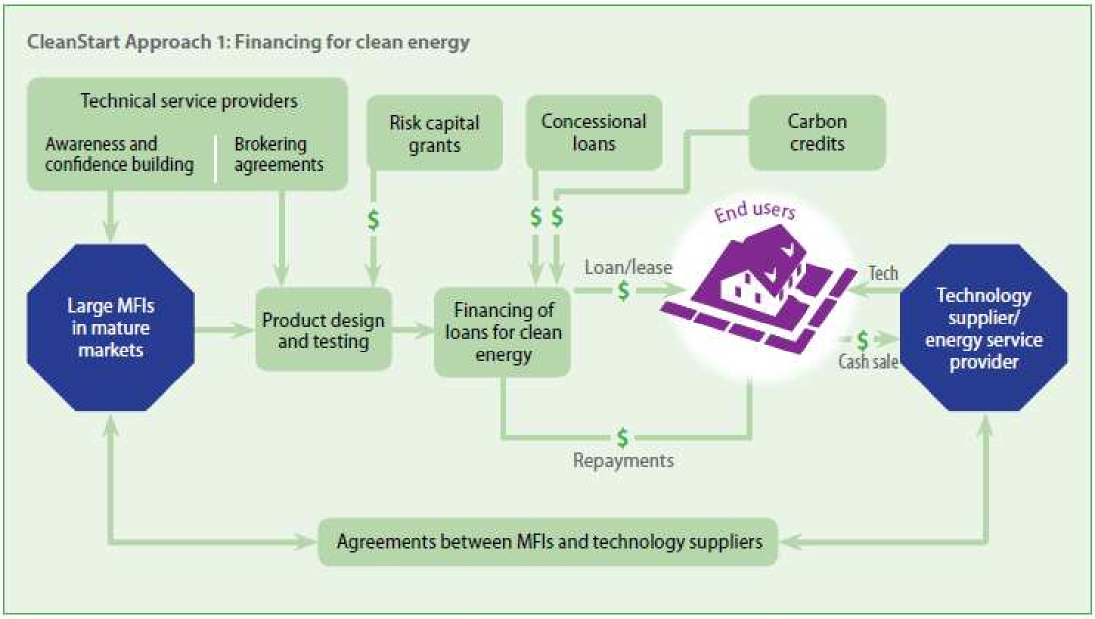

Figure 4: CleanStart model for financing clean energy (UNDP and UNCDF 2012)

Also according to Weimar 2010, as REN technologies are rather investment intensive for poor people adequate financing has to be provided and the risk and uncertainty of investment has to be countered. Efficient affordable after sales service as well as a politically favorable environment have to be offered. In many rural areas people are not aware of REN possibilities and hence this gap has to be closed. With such measures REN can be successfully promoted.

MFIs can include new profitable product segments and can enhance the quality of their loan portfolio by also offering loans for REN. In order to secure adequate funding carbon credit markets can be taken into consideration by MFIs (UNDP and UNCDF 2012). For promoting REN business and securing necessary funds the **Clean Development Mechanism (CDM)** can be used. It was launched by the Kyoto Protocol (Intergovernmental Panel on Climate Change – IPCC) in order to prevent climate change. The underlying idea is to assist developing countries to achieve sustainable development. Projects in developing countries which contribute to an emission reduction can earn so called Certified Emission Reduction credits (CER), which are equivalent to one ton of CO2. Industrialized countries can trade CERs to achieve their emission reduction targets, which they have agreed upon under the Kyoto Protocol.[39] The goal of CleanStart is to provide energy financing for energy starving people in developing countries instead of using subsidies, which are deemed to be less sustainable (UNDP and UNCDF 2012).

The empirical part of the paper will introduce GS' approach of financing clean energy. Afterwards the CleanStart model and the GS model shall be compared. Findings therewith may also be helpful for other MFIs intending to include REN into their portfolio.

2.1.12 Summary

This chapter first showed how microfinance evolved. It could be seen that it has been introduced to cater the poor who had formerly been excluded from the formal financial sector owing to lack of collateral, etc. and who were therefore facing exorbitant interest rates requested from informal moneylenders. Afterwards the underlying economics of microfinance, which shall be regarded when offering microfinance services, have been discussed. Wrenn 2005 showed that microfinance can have a positive impact on economic variables and human and social capital.

[39] http://cdm.unfccc.int/about/index.html

Moreover, the fundamental principles of microfinance, namely application of joint liability, frequent repayment, sequential lending, etc. have been presented. Microfinance comprises various products, however, as already mentioned this paper focuses on microcredit. Related interest rates have also been discussed. This chapter introduced the main players in the microfinance sector, namely MFIs, funds, investors, women borrowers, rating agencies as well as an online platform called Mix Market which provides performance transparency to the sector. Further lessons learnt from the perspective of the different microfinance players have been presented.

Finally the chapter showed the opportunities for microfinance and REN in developing countries. The chapter showed how the vicious cycle of energy poverty can be overcome by using access to energy to foster productive enterprises and to increase income therewith. The possible synergy between MFIs, microenterprises and REN has been depicted and the UN CleanStart business model for financing clean energy has been introduced as an example. The following chapter will provide insights into the energy related problems of developing countries and will introduce different REN technologies which, dependent on local specifics, could be installed to tackle this issue.

2.2 Renewable Energy for Developing Countries

2.2.1 Energy related problems in developing countries

Inhabitants of developing countries often face the problem that electricity distribution is only concentrated on certain population centers and vast areas of the countries are off-grid. With access to electricity rural people would be able to improve their working situation by extending operating hours due to lighting. By use of REN working conditions can also be considerably upgraded as the working environment becomes cleaner and safer. Micro-entrepreneurs can possibly also benefit from an enlarged customer stock when they possess lighting, fans, TVs, etc. as such devices attract people and let them gather. REN can also power much needed machinery for productive use or to cool or dry goods. In addition, communication tools can be used, when having access to electricity, and can boost market conditions, etc. Moreover, children's education can be positively addressed, as lighting can be provided to schools, etc. (Allerdice and Rogers 2000).

The close correlation between human development and energy access is shown in the following figure. The **Energy Development Index** depicts a country's progress concerning use of modern fuels and describes the level of energy poverty (OECD/IEA 2010).

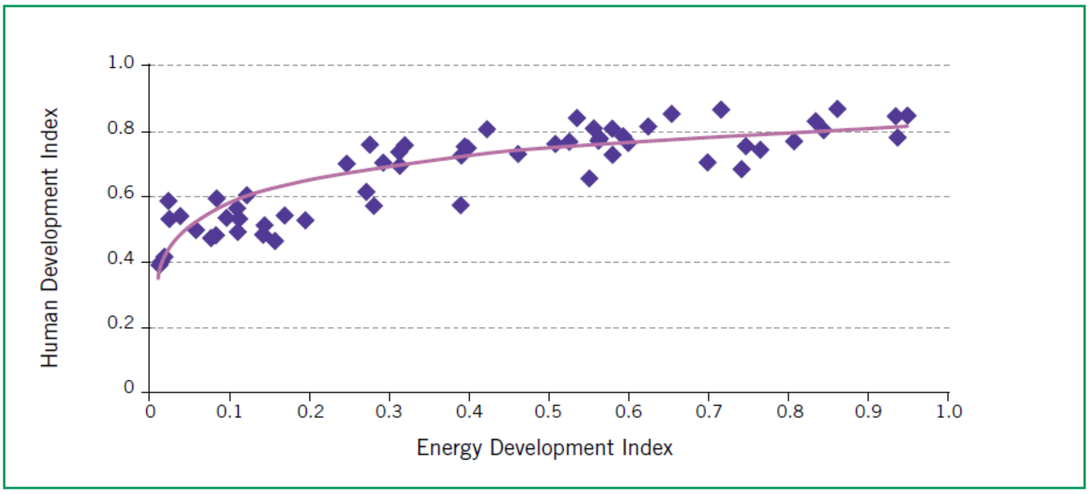

Figure 5: Comparison of the Human Development Index (HDI) to the Energy Development Index (EDI) (OECD/IEA 2010)

This becomes also evident in the case of Bangladesh, which is focused as country of research in this paper. As stated in the introduction Bangladesh is ranked 146 out of 187 countries by the HDI, which is rather low-end and it also shows a high level of energy poverty as only about half of the population has electricity access.

The importance of energy can also be shown by the **formula for value generation** (Q):

Q = C (t) + L (t) + CT -> **Q = C (t) + L (t) + E**

C stands for capital, L means labor and CT is the creative term representing innovation. CT has formerly been used and is suggested to be exchanged with E, which expresses energy input, as without energy supply labor cannot work properly and capital is not invested. Hence, lack of electricity is an indicator for a country's underdevelopment (Lindenberger 2001).

2.2.2 Rural electrification options with REN

2.2.2.1 General

According to the International Energy Agency (IEA) **Renewable Energy** is defined as *"Energy derived from natural processes that are replenished at a faster rate than they are consumed. Solar, wind, geothermal, hydro, and some forms of biomass are common sources of renewable energy."*[40] Also the International Renewable Energy Agency (IRENA) terms renewable energy as *"All forms of energy produced from renewable sources in a sustainable manner, which include bioenergy, geothermal energy, hydropower, ocean, solar and wind energy"*.[41]

Rural electrification options span wide from eg small solar or wind packages to larger scale solar, wind, micro-hydro or biomass systems (Allerdice and Rogers 2000). This section of the paper will provide an overview about the technical preconditions and general principles of photovoltaic (PV), biogas, biomass gasification, wind and micro-hydro technology for developing countries, as those applications are deemed to be relevant in this paper's country context. The related findings may also offer insights for possible technical solutions for other developing countries.

[40] http://www.iea.org/aboutus/faqs/renewableenergy/
[41] http://www.irena.org/Menu/index.aspx?PriMenuID=13&mnu=Pri

2.2.2.2 Photovoltaic (PV)

One option to use REN for electricity generation is photovoltaic. When planning to set up a PV installation the following has to be taken into account: The required load (watt-hours per week, also considering times and amount of usage) to supply used devices defines the number of PV modules as well as the corresponding battery size needed and a possible back-up energy system if not enough electricity is available through the PV plant and if no grid connection is available. Further the solar irradiance (the amount of solar power given; usually addressed by W/m²) in the area under investigation has to be determined. Therefore the "global solar irradiance" (also named total radiation), which includes the direct and the diffuse incoming solar energy on a horizontal plane onto the earth's surface, is a decisive factor. Diffuse radiation means radiation coming from all directions due to diversion by aerosols, dust and molecules. Direct radiation is sometimes also called beam radiation and is the radiation coming straight from the sun (Fechner 2012; Tiwari and Swapnil 2010).

Afterwards the optimum inclination and orientation of the PV modules for maximum power generation have to be assessed in the specific location and shadowing effects due to eg trees, buildings, etc. have to be taken into consideration. The investigation on possible shadows is crucial as in case a PV module of a string is covered by shadow all the other modules adapt and the power production is lowered considerably. Finally proper maintenance, comprising cleaning of the equipment and performing repair works as needed, during operation shall be undertaken (Fechner 2012; Tiwari and Swapnil 2010).

There are different cell options available, namely mono-crystalline silicon (exceeding 18% efficiency; sliced from grown ribbons; individual parts are called wafers) and poly-crystalline silicon (about 15% efficiency; sliced from castings) as well as thin film modules, where thin layers are deposited on low cost material such as glass, and further concentrator cells. Crystalline silicon cells have so far been used most, as thin film technology up-to-date shows much lower efficiency rates and not enough research has been undertaken in this field so far. Concentrator cells do not use diffuse sunlight, but focus light by use of an optical concentrator, are hence rather complex and not deemed to be suitable for the investigated purpose herein. The production steps of a crystalline PV system are depicted below. In addition to the PV modules the so called balance-of-system components (BOS) such as wiring, reliable mounting structure, etc. have to be considered (Fechner 2012; Luque and Hegedus 2011).

The following figure depicts the production steps of a photovoltaic crystalline system:

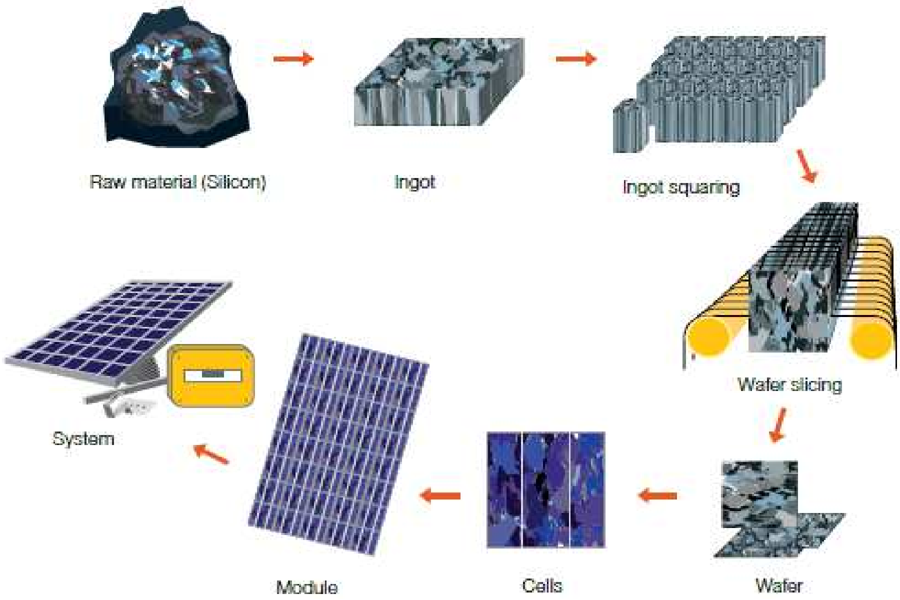

Figure 6: Photovoltaic Value Chain (EPIA 2009)

The principle of PV cells can be described as follows: due to sun irradiation electrons get separated from atoms. Electron holes emerge and free floating electrons are searching for electron holes. Voltage is generated when electron holes (positive) and electrons (negative) assemble at the P-N junction (positive and negative semiconductor) and electricity is generated when leading wires are connected (Goetzberger und Hoffmann 2005). Only a certain range of the solar spectrum can be used for crystalline silicon PV, namely wavelength of approximately 300 nm - 1200 nm (The German Energy Society 2008).

For usage of the produced electricity respectively for connection to a grid, if available, an inverter is necessary to convert the direct current (DC) power generated by the PV modules into alternating current (AC) and also to optimize the electricity output by finding the point of maximum power, which is undertaken by the inverter. In order for being able to separate the inverter from the PV generator, eg for service works, a DC switch has to be installed. In case of stand-alone PV systems (with no connection to a public grid), a battery is crucial to ensure electricity supply throughout day and night. Therefore also a charge controller is required, as overloading respectively low discharge can be prevented therewith. Moreover, installing a monitoring system is advisable to get an overview of electricity production and for being able to detect problems fast (Fechner 2012; EPIA 2009).

2.2.2.3 Biogas

Another option for electricity generation is biogas. Starting off in the 1950s, nowadays already plenty of biogas plants for households or for small communities can be found in developing countries, such as China, India, Nepal, etc. (Gautam et al. 2009).

Production of biogas (methane) is performed by anaerobic digestion through bacteria in the absence of oxygen. The energy content of 1 m^3 methane is approximately 10 kWh. As feedstock a wide range of materials can be used, eg animal excrement, such as cattle manure, agricultural crops, food residues, organic waste. The produced gas can be converted into electricity by use of a gas engine or gas turbines. So far, the latter have been less frequently used (FNR 2009).

In principle, different parameters shall be monitored during the process, namely temperature, hydraulic retention time, organic loading rate, ammonia concentration, trace nutrient and metal supplements and methane production enhancers. Adequate monitoring of the biogas production rate and the gas composition shall be secured to derive optimized results. In order to enhance the biogas yield and to improve the quality of the remaining fertilizer, co-digestion (mixture of feedstock substances) is advisable. In case of use of critical raw material, such as animal by-products, hygienic requirements have to be observed. If waste material is used, mechanical biological treatment as well as waste source separation plays an important role. In order to use the biogas it has to be upgraded. Hydrogen sulphide and carbon dioxide has to be removed. This is performed by different filters and scrubbers (Wellinger and Harasek 2012). However, the just stated implies an optimized but rather complex biogas production procedure, which is inherently too sophisticated and yet too expensive for being applied in developing countries. Nevertheless, due to further research and economies of scale it might be relevant in the future. The next paragraphs will provide an insight into presently suitable biogas options and related procedures for developing countries.

When designing biogas plants for usage in developing countries certain aspects shall be considered. The biogas plant concept shall be kept simple and shall not compose of moving parts or metal parts which could lead to corrosion. Locally available respectively trainable personnel shall be employed for construction. In addition, biogas plants shall be designed in a way such that local materials can be used. Minimum maintenance shall be required for such plants. The lifetime of a plant shall reach about 20 years. Overall such biogas plants shall be designed to have a positive impact on the local economy. Dependent on the purpose (requiring a domestic [eg for 5 persons] or institutional [eg for 500 persons] plant) biogas plants can be scaled up accordingly by using the same skills respectively training and same materials (Lebofa and Waldow n.a.).

There are different digester designs available. In developing countries mostly the Chinese fixed dome digester, the Indian floating drum digester and more recently the tube digester have been applied. The fixed dome solution is usually built with local material, such as clay, bricks, whereas the floating cover digester is made of concrete and steel and the tube digester is constructed by use of folded polyethylene foils and porcelain pipes to be used as inlet and outlet. Those digesters are usually filled by human and animal waste to provide gas (eg 0.5 m^3 biogas per m^3 digester volume [which is about 5-10 m^3 on average]) for single households for cooking and lighting (Plöchl and Heiermann 2006).

The process of the different digesters is very similar. The feedstock is led to the digester tank via the inlet pipe, where it stays 10 to 30 days (average retention time). The produced gas is collected through a pipe in the cover top and the digested slurry exits the digester through an outlet pipe. The digesters do not have mixers installed to move the slurry, facilities to maintain a certain temperature or to remove stones, etc. Hence, those digesters are less controllable and their volume and therewith also efficiency is often decreased as stones, non-degradable organics, etc. are not removed. This can also lead to blockings of pipes. Therefore, the process should stop at times for being able to remove such materials. Tube digesters are very low cost and can be exchanged in case of low efficiency. The following figures depict the three different types of digester (Plöchl and Heiermann 2006).

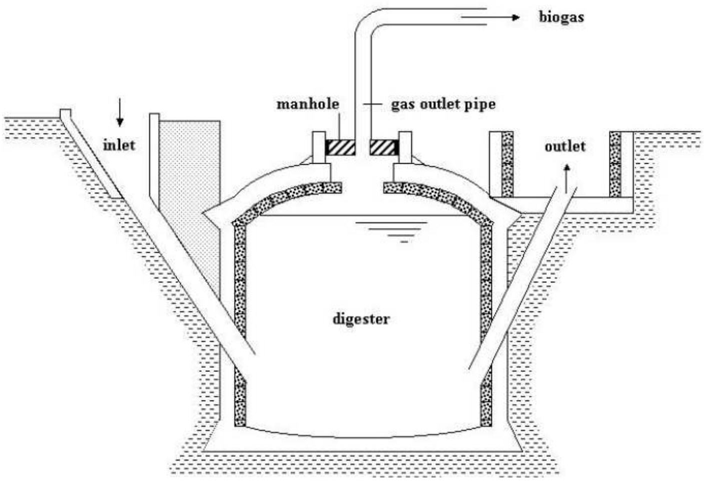

Figure 7: Chinese fixed dome digester (Plöchl and Heiermann 2006)

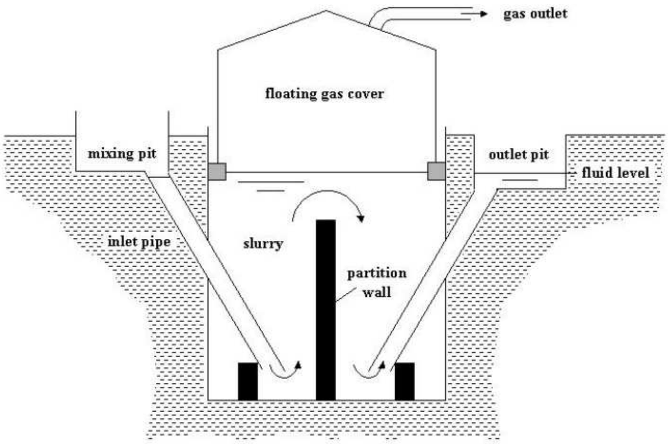

Figure 8: Indian floating cover digester (Plöchl and Heiermann 2006)

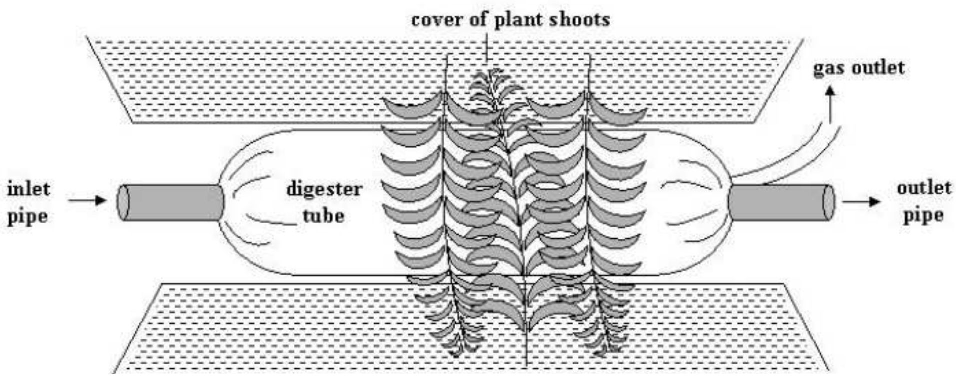

Figure 9: Tube digester (Plöchl and Heiermann 2006)

The above presented digesters are advantageous for application in developing countries as they are inexpensive (Chinese/Indian type digester investment costs: about 500 EUR to 1,000 EUR per plant; tube digester investment costs: 30 EUR to

50 EUR), local materials can be used, they are easy to handle and do not possess moving parts which may become a source of failure (Plöchl and Heiermann 2006).

When having abundant feedstock available producing biogas can be a very advantageous option for facilitating cooking, lighting and electricity generation in developing countries. People can save on energy costs, as they do not have to purchase energy elsewhere and by producing their own biogas they can even generate additional income by selling it. Further, as methane, which is showing a global warming potential 21 times higher than that of carbon dioxide, is captured from anaerobic digestion in case of biogas production, significant environmental benefits can be achieved. Another very positive aspect in biogas production is that organic fertilizers are made available as by-product, which can be used instead of chemical fertilizers and hence this can also lead to cost-savings. The biogas slurry can be used by farmers to improve crop growth and to water plants during dry periods. Crops can become more reliable and healthier. Moreover, due to the biogas production process hygienic standards can be considerably increased as germs, such as cholera, etc. are destroyed and odor can be reduced. Also people, especially women, can save time as they do not have to spend it to collect fire-wood, etc. (Hasan and Khan n.a.)

Biogas could be produced using a community model, which means that manure and bio waste is collected from households free of charge, then converted into biogas in a central plant and then along with organic fertilizer distributed again to the community. Dependent on each specific project adequate gas prices have to be evaluated. One of the most important issues to promote biogas adequately is to raise public awareness (Hasan and Khan n.a.).

2.2.2.4 Biomass Gasification

When thinking of biomass as source for electricity generation various applications are available. This paper will focus on usage of producer gas in combustion engines as this technology seems cost- and execution-wise to be the most feasible solution for developing countries. Introducing other generally possible technologies, like combustion steam electric power generation or fuel cells would go beyond the scope of this paper.

Gasification comprises a conversion of organic materials at temperature levels above 700°C and at an air ratio level, called lamda, between zero and one. Lamda is defined as the amount of oxygen supplied to the process divided by the minimum amount of oxygen necessary for full combustion of the biomass. As gasification agent air, O2, steam or CO_2 can be used (Hofbauer 2012).

In all applications the biomass is first dried, then devolatized (formation of char) and then gasified. The necessary heat can be produced within the reactor itself through partial oxidation, also called autothermal gasification, or by heat exchangers, which is called allothermal gasification. In order for being able to use the producer gas in gas engines it has to be liberated from particles and tar by fabric filters and scrubbers, which are also cooling down the gas so that it can be used in a gas engine. Gas engines are usually used for small scale and gas turbines for large scale applications (Hofbauer 2012).

There are different reactors which can be used for this process, namely fixed bed, fluidized bed and also entrained flow reactors, which are depicted in figure 1. The latter is applied in case of small biomass particles (grain size smaller than 0.1 mm), gasified within few seconds at temperatures between 1200°C and 1500°C and will not be further discussed herein as this design is only economically feasible in case of larger plant sizes (Lettner et al. 2007). Also the fluidized bed application is recommended for larger scales from 0.5MW upwards. Its product gas shows a quite high tar content, which is unfavorable and leads to the necessity of more complex equipment for further treatment (FAO 1986). Hence this paper will focus on the fixed bed gasifier.

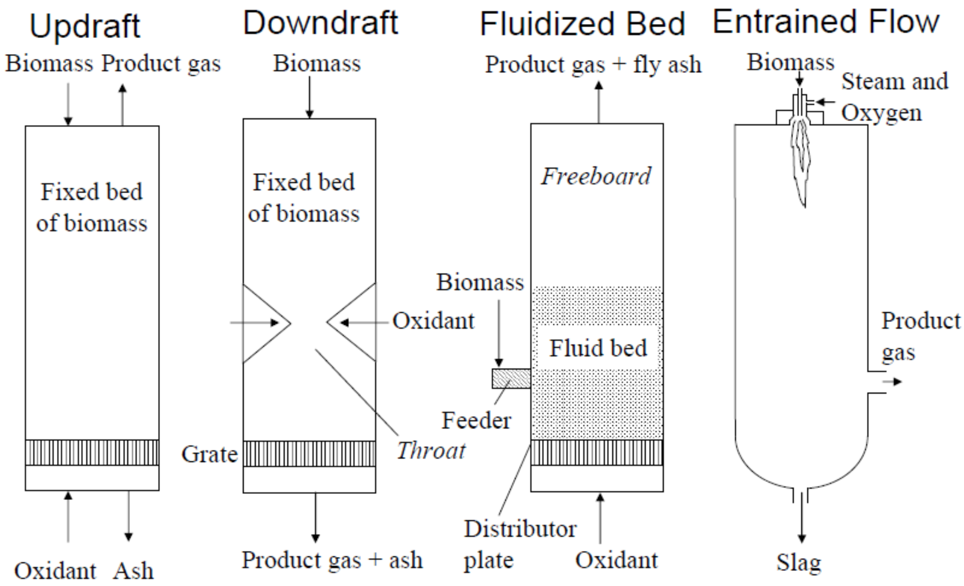

Figure 10: Overview of biomass gasifiers (Wallace 2008)

For small scale applications a **fixed bed solution with downdraft** design could be used, as it is rather simple to build and the maintenance shows lower requirements. In such systems biomass is fed from the top and the feedstock and the gas move downwards. The gasification agent (air) is introduced above the bottom. Biomass is dried and pyrolysed. Then the resulting char is oxidized (CO2 and H2O is released) and undergoes reduction (CO and H2 is formed), resulting in a combustible gas mixture. Afterwards the gas can be burned in a gas engine. As not all gases pass through the hottest zones and their residence time is too short, a tar-free gas is rarely achieved. In principal also updraft designs could be chosen, however, those show a higher rate of tar production than downdraft solutions, which is not practicable in case the producer gas is to be used in engines for electricity generation. Updraft designs are rather used for direct heat applications (Hasan et al. 2009; Nuol n.a.; Lettner et al. 2007; Larson 1991).

The advantages and disadvantages of the different gasification options are shown in the following table (EPA-CHP 2007):

Table 1: Advantages and Disadvantages of different Gasifiers (EPA-CHP 2007)

Gasifier	Advantages	Disadvantages
Updraft fixed bed	Mature for small-scale heat Can handle high moisture No carbon in ash	Feed size limits High tar yields Scale limitations Low heating value gas Slagging potential
Downdraft fixed bed	Small-scale Low particulates Low tar	Feed size limits Scale limitations Low heating value gas Moisture sensitive
Fluid bed (Bubbling and Circulating)	Large-scale applications Feed characteristics Can produce higher heating value gas	Medium tar yield Higher particle loading

Different kind of **feedstock** are in principal usable for biomass gasification, namely forest wood residues (wood chips, pellets, etc.), agricultural residues (sugarcane bagasse, rice husks, coconut shells, corn cobs, peanut shells, etc.) or energy crops (switchgrass, willow, etc.). Depending on the characteristics of the biomass different problems can occur. For example, tars accrue due to lignin and slagging due to silica and potassium in the feedstock (Agblevor 2007; Salam 2010).

Forest residues have a high lignin content and are high in ash and show particulate matter. Crop residues show an ash content of 5-15 wt% and a high silica content. Herbaceous biomass is high in ash and in silica. Woody biomass, like poplar, shows a low ash content, low silica, but a high cost of production (Agblevor 2007).

Biomass feedstock varies in moisture, density, size and carbon content. In principal all kinds of biomass with a moisture content between 5% and 30% can be used for gasification. The biomass has to be prepared for gasification by feed size reduction (chopping, pelletizing, etc.) and drying. Considerations have also to be taken concerning storage and transport to the biomass plant and also within the plant, e.g. on screw feeders, bucket elevators, etc. (Salam 2010).

2.2.2.5 Wind Power

In order to assess whether wind power generation is suitable in a specific area the wind power density (W/m^2) and wind speed (m/s) shall be reviewed. It has to be regarded that the wind power is proportional to the cube of the wind speed, which means that when the wind speed doubles the wind power increases eight times. As wind speed and wind directions vary at sites, investigations have to be undertaken towards the frequency distribution (also called Weibull distribution, respectively Rayleigh distribution in case of a simplified approach) of wind speeds taking into account different wind speeds and their duration. Wind data can be gathered from meteorological stations and current measurements shall be compared with long-term data, if available. In the 1980s scientists in Denmark developed a method, called wind atlas method, to calculate the wind energy content of various sites. Therewith considerations regarding influence of terrain, hills, obstacles, etc. have also been taken into account. A computer program, called WAsP (Wind Atlas Analysis and Application Program), has been set up, with which the energy content at a given site can be calculated by using wind data from an existing wind measuring mast with long-term wind data, which are converted to wind atlas data (Wizelius 2007).

The energy of the wind is captured by the blades of wind turbines, which are fixed on a rotor to produce electricity. As the wind is stronger and less turbulent in higher regions, blades are often fixed 30 meters or higher above ground onto the wind turbine towers. Dependent on their size wind turbines can reach a power output of 100 Watt to 3 MW (Ferrey and Cabraal 2006).

Small wind turbines, which are of interest in this paper, can be classified into Pico-Wind (smaller than 1kW), Micro-Wind (1kW-7kW) and Mini-Wind Power (7kW-50kW). Pico-Wind systems are used for rural electrification of households and can be seen as counterparts to solar home systems (PV for single households). Such systems supply DC loads and are equipped with a battery (usually lead-acid), which stores and controls electricity. Further, hybrid systems, which are usually generating less than 50kW, can be installed, which incorporate not only a wind turbine, but also eg a PV system. For back-up power diesel generators can be included. In addition to a battery those systems usually have an inverter to generate AC power loads. For larger off-grid systems diesel generators are usually a fix part of the system to secure ongoing power supply (EWEA 2009).

In case of small wind turbines usually permanent magnet generators, direct drive, passive yaw control (preventing twisting cables) and two to three blades are used. As it is rather cost and time intensive to gather accurate wind data by undertaking extensive measurements, site selection is often based on expert views and estimations for small wind turbines. In case of wrong assessments, poor performance has to be expected. Further, small wind turbines have low towers, as this saves cost, and are often placed close to settlements. Both may lead to low capacity and exposure to heavy turbulences. Small wind turbines for developing countries have to be robust, reliable and easy to maintain. Hence, vertical-axis technologies, which are less influenced by turbulent air, require lower wind speeds for generation, show lower installation costs and emit less noise and vibration, are getting to be more interesting than the standard horizontal-axis turbines. However, vertical-axis technologies show lower efficiencies (EWEA 2009).

In case of vertical axis wind turbines the generator and gearbox can be installed at ground level. Hence, this type is easy to maintain and repair. There are two major vertical axis turbines available, namely the Savonius, in which case a vertical S-shaped surface rotates around a central axis, and the Darrieus turbine, which has two to four blades forming bows from the top (Wizelius 2007). Both types as well as the components of a typical wind turbine are depicted in the figures below.

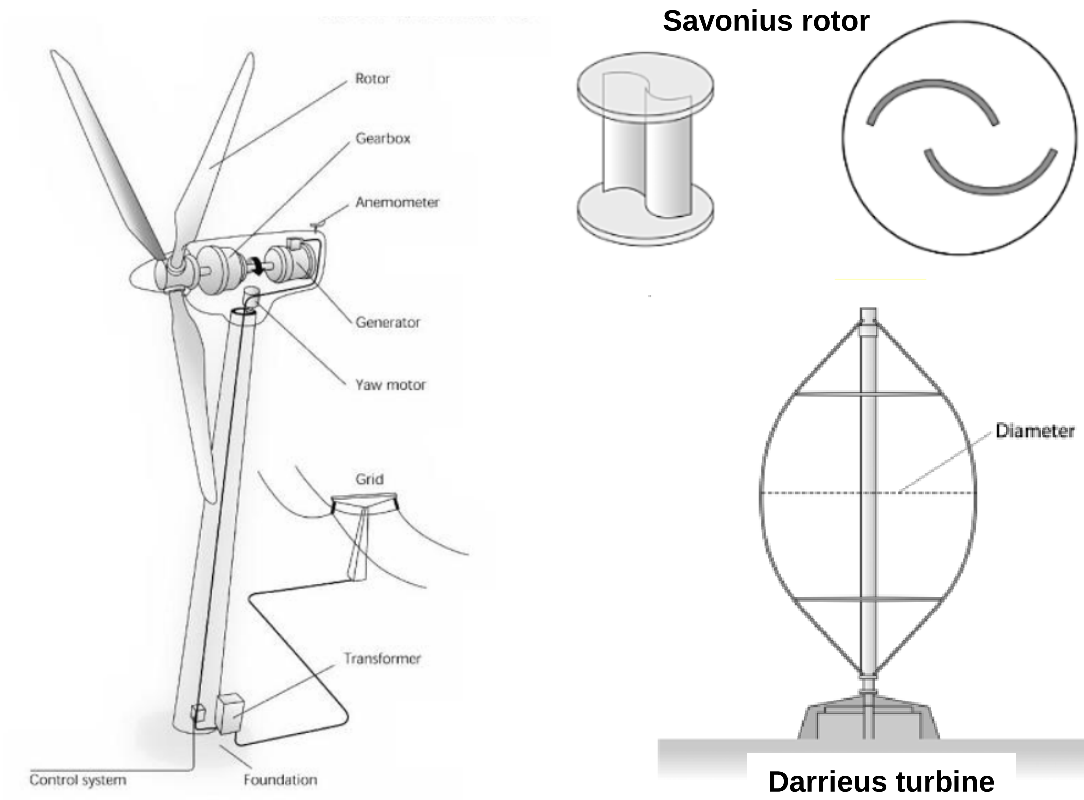

Figure 11: Main components of a wind turbine, Savonius rotor and Darrieus turbine (Wizelius 2007)

2.2.2.6 Micro-Hydro Power

Another option for the purpose reviewed herein is small hydro power plants (SHPPs). The definition of SHPP is country dependent, but in general the upper limit is about 10MW. SHPPs can be further classified into Micro-Hydro (1-100kW), Mini Hydro (100kW-1MW) and Small Hydro (1MW-10MW) (Breeze 2005). As small scale solutions are relevant for this paper, the focus herein lays with Micro-Hydro.

A hydro power plant's feasibility is dependent on adequate head drop (calculated by the difference in elevation head, pressure head, velocity head of intake and tail water level as well as losses due to hydraulic friction) and discharge (given by an area’s precipitation minus groundwater flow, evaporation, change in storage and water use) of a specific site. Hence, a proper geographical topography has to be given in order to make SHPPs viable (Blöschl 2012; Nag 2008).

When choosing a SHPP site several factors shall be considered: water availability (maximum, minimum and average discharge to decide on the plant capacity and to provide adequate spillways/gate relief during floods), water storage (to ensure continuous electricity generation), water head (the higher the head the less discharge is needed to generate a certain output), site accessibility (for transportation of equipment, etc.), distance from load centre (in case of connection to the grid, to lower cost of erection and maintenance of transmission lines) and land type (land should be cheap and solid; rocky land is preferred, as it withstands the stress transmitted from the dam) (Rajput 2006).

SHPPs can be high head (>10 m) or low head (<10 m; run of river type) plants. The hydraulic design of a SHPP consists of multiple sections. In case of a high head SHPP this comprises first of all of the water catchment area (intake). The stream intake consists of a weir and a settling basin, where sediments, which would erode the turbine blades, are separated and a trash rack, which is collecting floating debris. The sediments should be flushed adequately. Such water catchments can in principal be side intakes, where rivers are dammed by a weir, water is led into a settling basin and is then transported to the turbine, or drop inlets, where the water flows over an inclined rack and drops into a collecting channel, from which it flows into the settling basin. In addition, high head SHPPs show penstocks, a surge tank (in case of heads above 100m; to compensate for the sudden decrease in flow acceleration or deceleration, also called water hammer) and the power house containing the electro-mechanical equipment. In contrast, low head SHPP comprise of a fixed or gated weir (in case of the latter one the water level can be controlled by a gate), a powerhouse and a fish pass (Drobir 2012; Mukherjee and Chakrabarti 2004).

The powerhouse contains the turbine, the generator, protection and control system, dewatering and drainage system, auxiliary power system, foundation, emergency and stand-by power system, lighting and ventilation. Through the water inflow the turbine is spinning and driving the generator via a shaft, which is then producing electricity through an electro-magnetic field (Mukherjee and Chakrabarti 2004).

Concerning the turbine there are three major designs, Kaplan, Francis and Pelton turbines, which can be divided into reaction and impulse turbines. In case of reaction turbines (Kaplan and Francis) the water flow through the turbine creates different pressure onto the blades and therefore causes them to spin. In contrast, impulse turbines (Pelton) are operating under almost atmospheric pressure, as the potential energy of the water is fully converted into kinetic energy already before flowing through the runner (Meier 2001). The following figure presents a typical cross section of a hydro power plant.

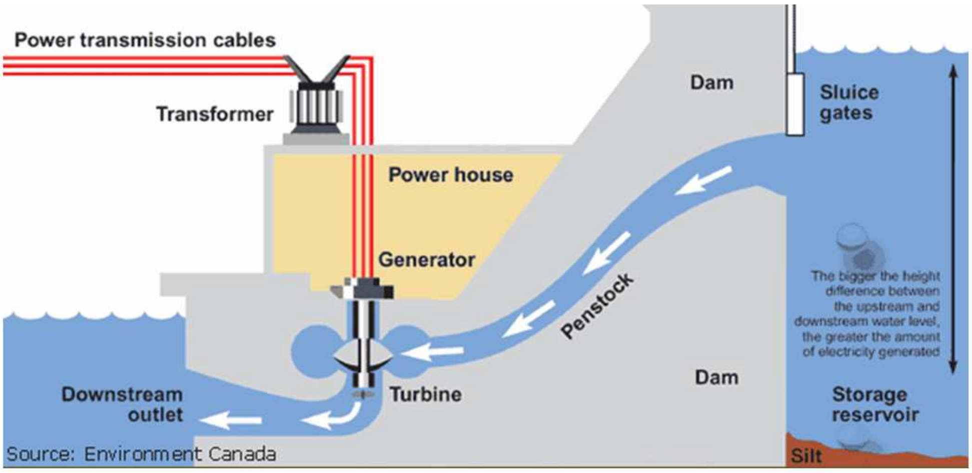

Figure 12: Cross section of a small hydro power plant[42]

As an alternative to turbines used for electricity generation also standard centrifugal pumps used as turbines can be an interesting solution. The advantages of use of pumps are low investment costs, sufficient efficiencies (up to about 86%) and short equipment delivery time as standard components can be used. Further, relatively light weight of equipment is favorable during installation and maintenance works are rather simple. Dependent on the pump type eg a head of up to 80m with discharge of up to 0.8 m³/s or up to 6 m³/s in case of double suction pumps and heads of up to 350 m and discharge of 0.25 m³/s by use of multi-stage pumps can be reached. Hence, pumps are very well suited for micro-power stations parallel to the grid. However, it has to be considered that regulation of the pump is only possible via

[42] http://www.buet.ac.bd/ces/rezaur-rahman.ppt#12

throttling. Pumps only show one optimum duty point as they do not have a movable guide vane apparatus like turbines. Different pump sizes can also be combined in one station respectively a frequency converter can be used to reach maximum efficiencies for a small optimum area (Mellacher 2012).

According to Mellacher 2012 the main components for a micro hydro power station comprise a wear resistant impeller as well as a spiral casing and an electrically operated flap for water level regulation respectively emergency shutdown. In addition a low voltage generator and a switch cabinet, including an electronics control and protection equipment, etc. are used.

2.2.2.7 Hybrid REN systems and Mini-Grids

REN technologies, such as PV or wind, as introduced above can also be used in a hybrid system also including a diesel generator, which provides advantages over a stand-alone REN system, as permanent and reliable electricity supply can be ensured therewith. In such systems the electrical energy generated by the REN technology is converted into chemical energy in a battery, which can again be converted into electricity when needed. The batteries hence act as a buffer and secure stable output during times of unfavorable weather, which reduces power production by eg PV plants. Diesel generators can also be used to charge the batteries or to directly supply electricity. Whenever feasible the REN installation shall be used for electricity production. Control mechanisms shall be set up to turn off the diesel generator when it is not needed. In case of hybrid systems which supply power to small villages AC electricity is directly fed to the load and in case of household installations DC power is produced which is entirely sent to a battery, which then feeds a DC load or an AC load by using an inverter (Blanco 1995).

In case of a hybrid power system different electricity producing and storing technologies can be combined. In order to secure on-going electricity supply the energy demand and the resources at a certain location shall be precisely assessed (Ghosh and Prelas 2011). The following figure depicts a solar-wind hybrid system.

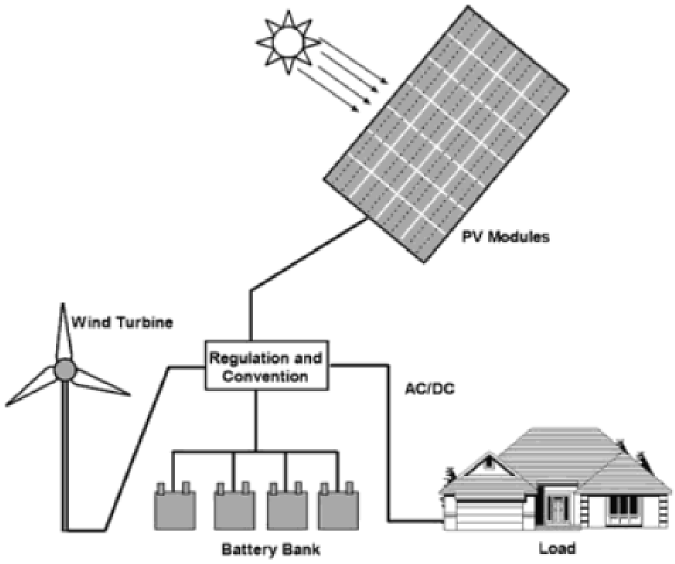

Figure 13: A solar-wind hybrid power generation system (Ghosh and Prelas 2011)

The hybrid systems presented above may provide proper solutions for electrifying rural areas of developing countries. However, the financial feasibility of such projects has to be assessed case by case. Also other REN technologies (such as biogas, etc.), dependent on locally available resources, are deemed to be usable for a hybrid system. However, going into details in this regard would exceed the purpose of this paper.

As mentioned before, the REN technologies presented in this chapter can be used in very small scale for single households or for extended scale (for villages) which can be facilitated by use of a mini-grid.

According to Prull 2008 *"A mini-grid can be defined as a semi-autonomous electric power generation and distribution system appropriate for small populations. Mini-grids are essentially a subset of hybrid power systems (typically low penetration systems) designed to meet the electricity demands of small remote sites with low cost being a chief concern"*.

By use of a mini-grid, which is typically powered by diesel generators, tens to hundreds of village households can be supplied with electricity. Instead of diesel generator sets also different REN options, such as PV or wind power installations, could be used. In order to secure electricity supply up to a few days mini-grids are usually equipped with large battery banks (Prull 2008).

A challenge therewith may be the household connection to the mini-grid. MFIs can be supportive in this regard by helping to handle the cost of connection charges including costs concerning energy meters. Initial connection charges could also be waived at the beginning by rural energy utilities and instead monthly connection fees can be levied during times of electricity supplied (Bhattacharyya 2013).

Through bundling of different REN projects respectively sources economies of scale could be availed and feasibility and sustainable management of such projects can be achieved. Finance and carbon benefits may be more easily obtained and operation and maintenance may be eased (Bhattacharyya 2013).

When thinking of mini-grids in rural areas, adequate control and monitoring have to be secured. A smart unit can be used therefore, which compares power generation and loads power demand. In case demand is exceeding generation then some loads according to priority will be cut and powering of critical loads will be secured. If surplus power is generated then new loads will be connected by the system. Grid data, such as voltage and current, are transmitted to a centralized server for monitoring. Such a smart unit can be used in rural areas of developing countries as it is simple and effective. The figure below depicts a smart unit presented by Prajapati et al. 2012, which is not only considering a mini-grid but also a main-grid being available. “L” displays the loads and “R” represents the automatic switches to select the power source (Mini-Grid versus Main-Grid). The loads can be switched on or off by manual switches “S”. The dotted box indicates the communication medium. So far, it has only been tested under laboratory conditions and shall be further investigated to make it practically feasible (Prajapati et al. 2012).

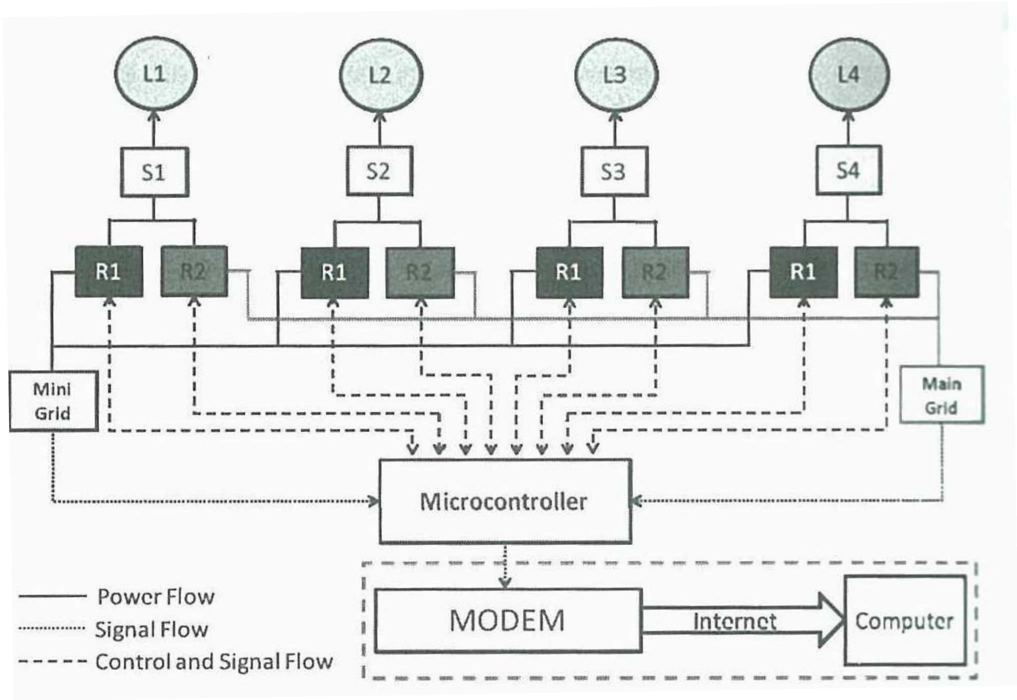

Figure14: Schematic diagram of a smart unit (Prajapati et al. 2012)

2.2.2.8 Community REN models

In order to make any type of REN economical, affordable and feasible **community REN models** can be used, which means that members of a community join and invest into a common REN project in the vicinity. For maximizing social benefits a part of the profit generated by such REN installations can be used to eg open a recreation center. A cooperative can be formed in order to manage the fund raising. Such a community REN model may entail various benefits, such as creating jobs, boosting local economy, increasing technical skills and capacity building, reducing dependence on fossils and matching generation and consumption due to raised awareness (which may also lead to energy conservation). Further, it provides environmental benefits and may increase people's interest in and enthusiasm about REN and may even become a source of pride and identity for a community (CEC 2010).

For establishing a community REN project, community meetings shall be held and all members shall be asked for participation by providing an input, raising questions, discussing concerns, etc. Thereby it is important to provide the community members with all relevant information and to raise awareness of their REN potential in order to secure informed decisions. Adequate relations and trust have to be built. Possible leaders have to be screened. Proper projects shall be identified and prioritized.

Relevant legal respectively permission aspects have to be reviewed and respected. Full community engagement has to be secured and technical (including grid), financial and environmental aspects have to be taken into account (CEC 2010).

As stated above cooperatives (co-ops) can be established to organize a community REN project. Co-ops have shown to be financially sustainable and to provide social and environmental advantages. In contrast to conventional businesses co-ops are jointly owned by its members who have one vote each, independent on their amount of shares. Further, they usually have also social respectively environmental or also educational targets and may be run as for-profit or not-for-profit business. In case of not-for-profit co-ops show various advantages, as the organization in such case does not have to pay corporate income tax and marketing may be easier as the co-op apparently follows values beyond pure financial gains. In any case, a co-ops surplus can be returned to its members via dividends onto their shares. Returns can be based on the number and class of shares. Moreover, co-ops rather entail long decision-making processes due to the amount of voting people. However, once a decision has been taken there is strong commitment by all people involved. Co-ops recognize the various stakeholders of a business as they can be made of consumers, workers, producers, investors, etc. For being successful, co-ops shall have clear goals, values, structures and stakeholders shall be well defined (CEC 2010).

By use of a co-op community members can also benefit from bulk purchases of equipment or operation and maintenance services, etc. by achieving better prices. Moreover, sales can be facilitated respectively emission credits can be easier obtained in case of common production. The power generated by a REN co-op can be directly sold to its members. Hence, cost-effective electricity can be provided. Investments can be based on estimated electricity consumption. With a co-ops surplus also further REN facilities can be purchased (CEC 2010). The use of co-ops and community REN models is rather novel, hence not much related literature can be found and further prospective research shall be undertaken.

2.2.3 Summary

Chapter 2.2 first described the energy related problems of developing countries. It showed that vast areas of developing countries are not electrified and that human development strongly correlates with energy access. Further, the formula for value generation has been introduced which showed that energy supply is a precondition for value generation and lack of electricity is an indicator for underdevelopment.

Then the term Renewable Energy has been defined and different REN technologies for developing countries have been presented. The following applications have been introduced: Photovoltaic (crystalline silicon PV modules), Biogas (Chinese fixed dome biogas digester, Indian floating cover biogas digester, Tube biogas digester), Biomass gasification (focusing on fixed bed down draft biomass gasifier), Wind Power (including conventional and Savonius and Darrieus turbine) and Micro-Hydro Power (including centrifugal pumps as turbines).

Finally, the idea of hybrid REN systems and mini-grids as rural island solution as well as the community REN model as financing option have been presented. In the following chapter the country of research including its power sector will be introduced.

3 Part II – Empirical study

3.1 Bangladesh - A country overview

3.1.1 History

After having been part of the British Empire via British India and after belonging to Pakistan, Bangladesh achieved independence in 1971 and has been established as parliamentary democracy. Bangladesh has often experienced political instability with riots, etc. Since 2008 Sheikh Hasina, member of the Awami League, has been prime minister (Ali 2010).

After the country's independence the government first followed a nationalization approach as it wanted to promote industrialization, however this led to inefficient processes and stagnation. Later on, up from the 1980s, Bangladesh decided for liberalization but faced the problem of heavy corruption. The government tried to put more focus on imprisoning corrupt people in order to tackle this problem (Weimar 2010).

3.1.2 General

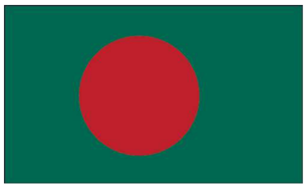

Figure 15: Map and flag of Bangladesh[43]

[43] https://www.cia.gov/library/publications/the-world-factbook/geos/bg.html

The People's Republic of Bangladesh is a country in Southern Asia between Myanmar and India with a total area of 148,393 km² (thereof 10,090 km² water and 55.39% arable land), a coast line of 580 km, an elevation between 0 m and 1,230 m (Keokradong) and a tropical climate. Much of Bangladesh is flooded during the summer monsoon season every year and droughts and cyclones are experienced. All this constrains economic progress. The Ganges (Padma), Jamuna (Brahmaputra) and Meghna river are forming the country distinctly. Therefore, most of the country is situated on deltas (International Business Publications 2011). The ongoing climate change and inherent global warming pose significant threats to Bangladesh, as this leads to more floods, cyclones, frequent and elongated droughts and increased sea levels (UNDP, GEF and IUCN 2006).

The country counts 161 million people (2012 est.) with a population growth rate of 1.6% (2012) and a labor force of 75.4 million. The population below the poverty line accounts for 31.5% (2010 est.) The literacy rate is 65.8%. The major cities are Dhaka (capital), with 14 million inhabitants, Chittagong, Khulna and Rajshahi. Bangladesh is divided into 7 administrative divisions (Dhaka, Chittagong, Kuhlna, Rajshahi, Rangpur, Sylhet and Barisal).[44] The country has 64 districts which are called zilas and 469 sub-districts named upazila (UNDP 2006).

Bangladesh achieved a growth rate of 5-6% each year since 1996 despite of political instability, lack of infrastructure and power supply and despite corruption. 45% of the country works in the agricultural sector, most of them in rice cultivation. 12% of the GDP can be attributed to garment exports and remittances from Bangladeshis leaving abroad. The GDP (purchasing power parity) in 2011 reached USD 283.5 bn. The countries inflation rate amounted to 10.7% in 2011.[45] The high inflation can be strongly attributed to the increasing oil prices. In order to consolidate the government's household the fuel subsidy had to be lowered (Weimar 2010). The commercial bank prime lending rate was 13.25% end of 2011. Exports reached USD 19.8 billion and imports accounted for USD 33.9 billion in 2011.[46] Bangladesh faces some political hurdles with its neighbor countries Myanmar and India. However, it is part of regional initiatives, such as the South Asian Association for Regional Cooperation (SAARC) or the Bay of Bengal Initiative for Multisectoral Technical and Economic Cooperation (BIMSTEC) (Weimar 2010).

[44] Same as above
[45] Same as above
[46]http://elibrary-data.imf.org/DataReport.aspx?c=1449311&d=33060&e=161843

3.1.3 Power Sector

The majority of the electricity generation in Bangladesh is derived from natural gas, approximately 67%. Other fuel type sources include furnace oil, diesel, coal and hydro power which can be seen in the following figure.[47]

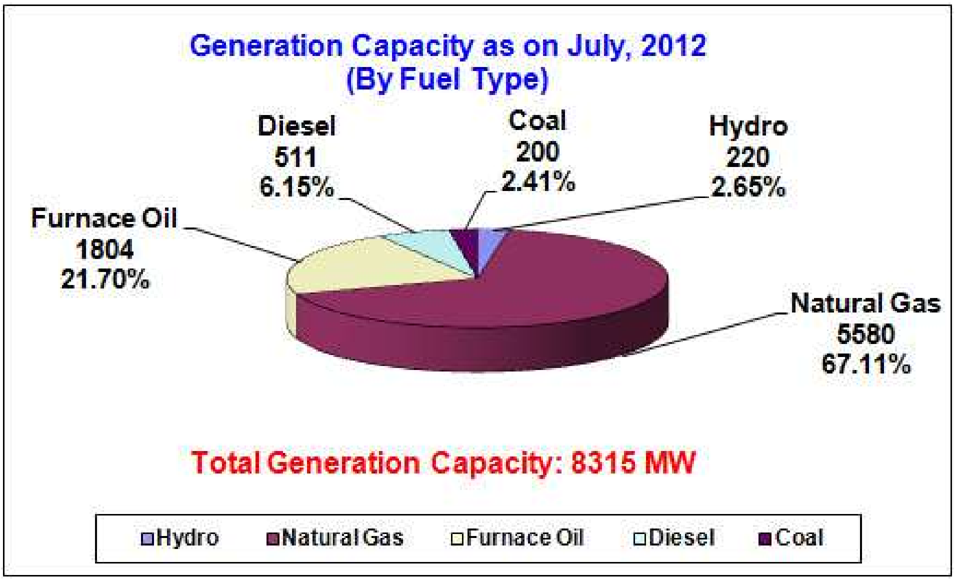

Figure 16: Bangladesh's electricity generation capacity in 2012[48]

Due to the fact of increasing prices for fossil fuels Bangladesh should think of exporting gas, etc. and should much more focus on local energy supply by REN. This would also be favorable because fossil resources are depletive. The Bangladesh government has so far followed a rather restrictive policy in regard to admission of international companies for investment into power generating facilities (Weimar 2010).

The electricity sector in Bangladesh is maintained by the government. The **Bangladesh Power Development Board (BPDB)** owns about 74% of the installed commercial electricity generation capacity. The **Power Grid Company of Bangladesh (PGCB)** is taking care of transmission and 5 companies are responsible for electricity distribution, namely BPDB in commercial areas, the **Rural Electrification Board (REB)** for rural areas connected to the national grid, the **Dhaka Electric Supply Association (DESA)** and the **Dhaka Electric Supply Company (DESCO)** for commercial electricity distribution in Dhaka and the **West**

47 http://www.bpdb.gov.bd/bpdb/index.php?option=com_content&view=article&id=5&Itemid=6
48 http://www.bpdb.gov.bd/bpdb/index.php?option=com_content&view=article&id=5&Itemid=6

Zone Power Development Company (WZPDCO) for commercial areas in the West of Bangladesh (Weimar 2010).

Hence, the majority of electricity generation and distribution in Bangladesh is handled by the **Bangladesh Power Development Board (BPDB)**, which is a statutory body, created in 1972 under the Ministry of Power, Energy and Mineral Resources, Government of Bangladesh. BPDB established the following subsidiaries: Ashuganj Power Station Company Ltd. (APSCL), Electricity Generation Company of Bangladesh (EGCB), North West Power Generation Company Ltd. (NWPGCL) and West Zone Power Distribution Company Ltd. (WZPDCL). In 2012 its generation has increased to approximately 8,100 MW. The board aims at expanding its generation capacity by 12,000 MW in the upcoming 5 years and 25,000 MW by 2021 in order to provide for reliable qualitative electricity.[49]

BPDB provides electricity generated from gas and hydro power in the Eastern part of the country and from coal and imported liquid fuels in the Western Zone, where the fuel cost per unit generated is much higher. Hence, electricity is transferred from the East to the West via a 230 kV inter connector transmission line. At some remote places and islands BPDB operates isolated diesel power stations, which are not connected to the national grid.[50] The following table provides an overview over the energy sector in Bangladesh.

Table 2: Energy statistics of Bangladesh[51]

Electricity production	35.7bn kWh (2009)	**Natural gas production/consumption**	20.13 bn m³ (2010)
Electricity consumption	34.83bn kWh (2009)	**Natural gas proven reserves**	183.7 bn m³ (2012)
Electricity installed generating capacity	5.819 million kW (2009)	**CO2 emissions from energy consumption**	56.74 million Mt (2010)
Electricity from fossil fuels	95.8% (2009)	**Refined petroleum products production**	24,790 bbl/day (2008)
Electricity from hydropower	4% (2009)	**Refined petroleum products consumption**	108,900 bbl/day (2011)
Electricity from other REN	0.2% (2009)		

[49] http://www.bpdb.gov.bd/bpdb/
[50] http://www.bpdb.gov.bd/bpdb/index.php?option=com_content&view=article&id=18&Itemid=7
[51] https://www.cia.gov/library/publications/the-world-factbook/geos/bg.html

The only large scale REN project of the country, a hydro power station, shows the following data:

Table 3: Karnafuli Hydro Power Station[52]

Name of Power Station/ Location	Number of Unit(s)	Unit Type	Commissioning date (DD/MM/YY)	Voltage Level (kV)	Type of Fuel	Source of Fund	Installed Capacity (MW)	Present (Derated) Capacity (MW)
KARNAFULI HYDRO (Kaptai) (230 MW)	2	Hydro	26-02-1962	132	Hydro	USA	40	40
		Hydro	08-01-1962		Hydro	USA	40	40
	3	Hydro	08-01-1982		Hydro	USA	50	50
		Hydro	11-01-1988		Hydro	OECF	50	50
		Hydro	11-01-1988		Hydro	OECF	50	50

The present Bangladeshi government (Ministry of Power, Energy and Mineral Resources) has already communicated in its election manifesto that the power sector shall be much more promoted. Their aim was an electricity generation of 5,000 MW in 2011 and 7,000 MW in 2013, which has already been exceeded. Until 2016 additional electricity generation of 15,000 MW is planned. According to the Bangladesh government's Power Sector Master Plan 2010 the demand of power in 2030 will be approximately 34,000 MW and the generation shall reach about 39,000 MW. REN and energy efficiency shall play a significant role therewith.[53]

The government aims at establishing a “Sustainable & Renewable Energy Development Authority” (SREDA), being in charge of REN, energy efficiency and energy conservation as well as the “Bangladesh Energy Research Council” (BERC) taking care of R&D in the energy sector. The ministry intends to have a 20 MW concentrated solar thermal power plant set up in the private sector for the first time. Further, it plans to generate 100-200 MW electricity from wind at the coastal areas and to produce 500 MW in course of a solar power development program assisted by ADB for remote areas. Community clinics, rural schools, irrigation pumps, etc. shall be served therewith and hence a contribution to the UNs MDGs shall be warranted.[54] From the above given, it can be seen that the Bangladeshi government set goals to foster REN. However, actual implementation of related installations has to be followed up.

In 1997 the Bangladesh government assisted by the International Development Agency (IDA; belonging to the World Bank) founded the **Infrastructure**

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[52] http://www.bpdb.gov.bd/bpdb/index.php?option=com_content&view=article&id=18&Itemid=7
[53] http://www.powerdivision.gov.bd/user/brec1/30/1
[54] http://www.powerdivision.gov.bd/user/brec/85/85

Development Company Limited (IDCOL), which is a non-bank financial institution caring for the financial gap for developing infrastructure and REN projects. An independent board of directors consisting of government officials, famous private sector entrepreneurs and a full time executive director and a chief executive officer are managing IDCOL.

In order to foster economic development IDCOL pursues the goal to facilitate private sector investment into energy and infrastructure projects by providing financial services. IDCOL received funds from IDA, GEF, KfW, German Financial Cooperation, GTZ, German Technical Cooperation, Netherland Development Organization (SNV), ADB, Islamic Development Bank (IDB) and Global Partnership on Output-Based Aid (GPOBA) for financing REN and infrastructure projects. IDCOL is also refinancing micro-credit provided by companies for REN promotion, channels grants to reduce costs and provides financial advisory and technical training assistance.

Concerning REN IDCOL focuses various projects. In 2003 IDCOL started the **Solar Energy Program** to promote SHS in remote areas. It planned to finance 50,000 SHS by mid 2008, which could already be achieved in 2005 and below budget cost. Further it targeted to finance 200,000 SHS by end of 2009, which has been achieved and afterwards it intended to finance 1 million SHS by end of 2012. This program is conducted through 30 partner organizations (POs), Grameen Shakti which is studied in detail in this paper being one of them. IDCOL was also engaged in setting up a PV based **micro-grid** with diesel generator back-up at Sandwip island/Chittagong and in solar installations powering irrigation pumps. Further IDCOL financed a 250 kW and a 400 kW rice husk **gasification** plant and is involved in financing of **biogas** plants and in production of related organic fertilizers.[55]

According to IDCOL (indicated by Sharif 2009) the proven indigenous gas resources of Bangladesh will be depleted by 2030 and the Bangladesh government aims at generating 5% of overall electricity from REN by 2015 and 10% by 2020.

[55] http://www.idcol.org/

3.1.4 Summary

Chapter 3.1 provided an overview about the country under research. First significant historical events, such as the split up from British India and later on from Pakistan, have been mentioned. Afterwards Bangladesh's geographic, demographic and economic situation has been presented. It could be seen that Bangladesh is one of the most populated countries worldwide with a very high poverty rate. Further, it has been shown that the country is prone to natural disasters and suffering from political instability, lack of infrastructure and corruption. Moreover, it became clear that agriculture plays a very important role in the country as almost half of the population works in this sector.

Concerning the power sector this chapter showed that the majority of the electricity generated in Bangladesh is derived from natural gas, which is depletive. Most of the installed capacity is owned by the public Bangladesh Power Development Board (BPDB), while power transmission is handled by the Power Grid Company of Bangladesh (PGCB) and power distribution by 5 other companies, dependent on the area. BPDB's operations and targets as well as the government's general REN targets have been presented. Finally the non-bank financial institution IDCOL, which receives funds from IDA, KfW, etc. and is therewith catering infrastructure and REN projects in Bangladesh, has been introduced. The following chapter will present the company Grameen Shakti which receives funding from IDCOL and is promoting REN in rural Bangaldesh.

3.2 Grameen Shakti (GS) – a success story

3.2.1 Excursus: Grameen Bank (GB)

"I am totally convinced from my experience of working with poor people that they can get themselves out of poverty if we give them the same or similar opportunities as we give to others. The poor themselves can create a poverty free world – all we have to do is to free them from the chains that we have put around them." This has been stated by Muhammad Yunus (2003a) in reaction to the UN Millennium Development Goal of halving world poverty by 2015. He claims that the economic and social system, the institutions and concepts which have been developed have created poverty as they hinder the poor to help themselves. In order to tackle this problem, Muhammad Yunus suggests that financial services shall be provided to the poor, everybody shall be recognized as potential entrepreneur and social entrepreneurship, which primarily follows social objectives instead of maximizing profits, shall be fostered (Yunus 2003a). Yunus 2006 mentioned REN to be a great idea for social business.

This principal idea came to his mind in the 70s when he lent USD 27 to 42 victims of money-lending businesses in the south of Bangladesh (Chittagong area) and experienced its great impact. Formerly eg a borrower took USD 0.25 of a money lender with the condition that goods produced by the borrower have to be sold to the money lender at any rate requested. Muhammad Yunus finally founded the Grameen Bank as financial institution (GB; "village bank") in 1983, which is owned by its borrowers and became self-reliant in 1995 by stopping to use donor money, and which became independent from domestic market loans in 1998 (Yunus 2003a). Each borrower takes one share, which is worth 100 Tk, and receives a yearly dividend, eg in the amount of 30% in 2011.[56]

GB aims at reaching the poorest on a sustainable basis by forming trust based relations. The target group (bottom poor) is selected by the criteria of people being "landless" (which means ownership of no more than a half acre of cultivable land) and "assetless" (implying material possession of less than the market value of an acre of land). Potential clients are thoroughly screened whether they can properly handle a loan. Borrowers form a homogenous (culture-wise, education-wise, etc.)

[56] Information provided by GB International Program Department in February 2013

peer group of five to nine members. Members of a peer group are deemed to monitor, support and motivate each other. Peer groups belong to a center, where weekly group meetings are held to collect installments, discuss problems, to introduce new products and to submit new loan proposals. Borrowers also receive training on all necessary loan aspects. Centers belong to branch offices, which are controlled by area offices, which are in turn monitored by zonal offices finally reporting to GB headquarters. GB's philosophy is to stay in close contact to its members and borrowers do not have to come to the bank, but GB will come to them (Latifee 2013).[57]

Loans are provided without collateral and are paid weekly with one week grace period. Affordable interest rates are charged (Latifee 2013). The average interest rate for loans of GB was 16% in February 2013. GB uses, as any typical bank, the approach of declined interest for loans and compound interest for deposits, unlike some moneylenders who use flat interest rates leading to higher costs for borrowers. No other "hidden" fees or charges are applied by GB. Different loan programs, which have been developed according to the customer's needs, are pursued, such as basic loan, flexible loan, housing loan, higher education loan, microenterprise loan and struggled member loan for the very poor. Most of the loans are perceived by GB to directly or indirectly positively affect income generation, as eg people taking a housing loan can build houses and use them as workshop for tailoring, etc. Basic loans are often taken to eg buy a cow and sell the milk at the market, etc. In case a borrower cannot properly pay installments at a certain point in time he or she can shift from the basic loan to the flexible loan program and therewith temporarily change the re-payment schedule and prolong the loan period. As per January 2013 the total rate of loan recovery reached 96.99%. Further, also a pension scheme, life insurance, loan insurance and scholarship are offered and public savings as well as savings from borrowers are accepted. Borrowers are also requested to undertake weekly savings, however this is not to be used as collateral, but only to motivate them to save money. GB does not on-lend those savings and borrowers can access them any time. The total balance of deposits in January 2013 amounted to 130,136.21 mio Tk.[58] The deposits as percentage of outstanding loans reached 161% in January 2013. Grameen Bank counted 8,399,202 members in

[57] Information provided by GB International Program Department and Branch Office Vouel in February 2013
[58] Exchange rate as of January 2013: 1 USD = 80.53 Tk (GB 2013)

January 2013, thereof 323,776 male members (GB 2013).[59] In order to secure accurate updated data, strong monitoring and transparency a computer software called “gBanker 5” is used for monitoring of loans and savings, accounting, fixed assets, inventory and payroll. This software (including installation and training) is also available for other MFIs, who can adjust the system according to their needs. In case of GB initial data entry is undertaken by the area office. GB follows a decentralized approach by delegating decision-making power to the rural group, center, branch, etc. Detailed internal audits lasting approximately 10 days are undertaken yearly complemented by two to three further small audits (Latifee 2013).[60]

GB formulated sixteen decisions which have to be observed by its borrowers, such as the four principles of GB (discipline, unity, courage and hard work), prosperity to families, new houses, growing of vegetables, keeping families small, looking after health, educating children, keeping a clean environment, boiling water before drinking, etc. Further, also 10 indicators of poverty alleviation of GB members have been established, related to eg sufficient meals, proper schooling, adequate health, etc. (GB n.a.). GB has developed a five star system for its branches and staff for 100% achievement of the following tasks: Green Star for 100% repayment, Blue star for earning profit, Violet star for self-financing, Brown star for all children of school age being in school, Red star for all members are moving out of poverty (Latifee 2013).[61]

Grameen Trust has been established in order to replicate the GB model abroad. As of November 2012 GB supported operations in the following countries: China, Colombia, Costa Rica, Guatemala, India, Kosovo, Mexico, Turkey and U.S.A. (Grameen Trust 2013). Grameen Trust provides management, consultancy, technical support, etc. It sends staff from Bangladesh to manage a new branch abroad for usually 1 to 5 years. After a one week feasibility study for a new branch an action plan is developed and rules and regulations are provided by Grameen Trust to be used as a guideline and may be adapted according to local specific characteristics. Eg in Bangladesh a branch office may service households in a

[59] Information provided by GB International Program Department and Branch Office Vouel in February 2013
[60] Information provided by GB International Program Department and Branch Office Vouel in February 2013
[61] Information provided by GB International Program Department and Branch Office Vouel in February 2013

radius of 5 km whereas in another country it may be responsible for a radius of 40 km due to less population density or installments may be collected fortnightly instead of weekly. Grameen Trust pursues different models, such as BOT (build, operate, transfer) and BOO (build, operate, own) abroad. Dependent on the model Grameen may transfer a branch office abroad to a local company after having been established and operated for a certain time or keep on staying to be the owner.[62] For creating microcredit banks (MB) some suggestions have been provided by Muhammad Yunus. He says that it is advisable to form MBs and to establish proper legal frameworks to allow such MBs to accept public deposits and savings from its borrowers. In such case MBs can mobilize deposits to finance loan operations and can become profitable. Donor money can be used for start-ups, training, research and development, technical support, etc. A separate legal framework and separate microcredit regulatory commission shall be set up to secure proper handling of the MBs business. A country's central bank can play a vital role therewith. NGOs which have formerly been engaged in the microfinance business can be converted into MBs. Further, also MB start-ups shall be encouraged by law. It shall be clearly defined by law that MBs primarily serve the bottom poor and preference shall be given to women. In order to prevent failure, fraud and mismanagement of a MB, arrangements for protection of deposits have to be made. Interests may be higher than in the case of commercial banks, but this is deemed to be legitimate due to the small loan size. However, interest rates and their calculation shall be fully disclosed to the public. MBs shall also be allowed to accept grants as they are focused on poverty reduction (Yunus 2003b).

Hence, as shown above there is great opportunity to considerably decrease poverty levels by use of microfinance which would also foster world peace. According to Yunus 2006: *"Peace is threatened by unjust economic, social and political order, absence of democracy, environmental degradation and absence of human rights."* For his outstanding engagement for the poor Muhammad Yunus received the Nobel Peace Prize in 2006. The following chapter will provide insights into one of GBs affiliates "Grameen Shakti", which is, as already mentioned before, dedicated to spread REN to the rural poor in Bangladesh and therewith contributing to sustainable development.

[62] Information provided by GB International Program Department and Branch Office Vouel and Grameen Trust (Mr. Chowdhury) in February 2013

3.2.2 History of Grameen Shakti (GS)

Grameen Shakti (GS) was founded by Muhammad Yunus, who is still the chairman of the board, in 1996 aiming at promoting affordable, clean, modern and sustainable REN technologies in rural Bangladesh to improve living standards while also taking care of the environment. Since then it has shown that providing REN to poor people in developing countries is feasible. In November 2012 GS achieved to have 1 million Solar Home Systems (SHS) installed in rural Bangladesh replacing therewith millions of liters of kerosene and reducing CO2 emissions. Over 1,000 SHS are installed per day by approximately 12,000 staff. About 8 million people already benefit from lighting homes and businesses with SHS, also leading to extended business hours.[63] Further, schools, clinics and mosques have been provided with solar power. Therewith the use of computers, TV, etc by pupils and use of lights for medical check-ups and operations as well as the use of refrigerators to store medication and vaccines could be enabled. Rural women could be empowered as they now can use chargeable portable lights at night and enjoy hence more security and increased mobility (Kamal 2012). Also multiple income generating businesses, such as mobile phone shops, electronic repair shops, health centers, etc. have been established. Grameen Technology Centers have been set up in rural Bangladesh which are locally assembling SHS accessories and therewith creating jobs, mainly for women, and help GS to be close to its customers and save cost. The company handles the largest non-grid program worldwide and is deemed to reach a further one million homes in 2016.[64]

The idea of GS got started by Muhammad Yunus contacting the Rockefeller Brothers Fund (RBF) in 1995 expressing his interest to experiment with SHS for the rural poor. RBF contacted the Solar Electric Light Fund, which in turn connected Muhammad Yunus to the Solar Power Light Company Ltd in Sri Lanka and Lotus Energy in Nepal. Together they created an action plan where solar panels were sourced from Sri Lanka, accessories from Nepal and batteries locally from Rahim

[63] http://www.gshakti.org/index.php?option=com_content&view=article&id=190:onemillionshs&catid=47:news-and-media&Itemid=73

[64] http://www.gshakti.org/index.php?option=com_content&view=article&id=190:onemillionshs&catid=47:news-and-media&Itemid=73

Afroz in Dhaka. Funding was provided by RBF and hence 20 SHS could be installed.[65]

GS has been operating very successfully and became one of the largest and fastest growing rural based REN companies worldwide. The company could tackle the initial problem of lacking a rural network and trained staff as well as missing financial funds. Further, it was able to overcome the challenges of absent awareness regarding REN among rural people and high upfront cost entailed with REN technologies.[66]

The company could profit from its mother company's (Grameen Bank) experience when designing financial packages for REN technologies, which has been supportive to reach economies of scale. Close contact to its customers and outstanding after sales service is one of the key factors of success. Rural people could be convinced that SHS are cheaper than traditional energy sources like kerosene. In addition to the SHS program GS launched a Biogas program in 2005 and an Improved Cooking Stoves (ICS) program in 2006, which has also proven to be very successful.[67] Further programs of GS include Organic Fertilizer, Grameen Technology Center, Tree Plantation, Wind Energy and Urban Solar Program (Kamal 2012).

3.2.3 Goal, Strategy and Facts

The objective of GS is to provide REN for rural areas and hence to contribute to affordable reliable energy supply, which can be used to replace expensive diesel and kerosene being usually used in those areas for powering electrical devices, lighting, etc. Further, GS aims at achieving health benefits due to less soot and other particulate matter which is usually encountered by using the above mentioned fossil fuels as well as at reducing GHG emissions. In addition the economic situation of rural locals is deemed to be improved by allowing for powering machines and creating jobs (Kamal 2012).

GS' strategy from the beginning was to follow a bottom-up approach which entailed to discover the real needs of the villagers. GS' intention has always been to provide

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[65] http://www.gshakti.org/index.php?option=com_content&view=category&layout=blog&id=52&Itemid=130
[66] http://www.gshakti.org/index.php?option=com_content&view=article&id=57&Itemid=77
[67] http://www.gshakti.org/index.php?option=com_content&view=article&id=57&Itemid=77

tailor-made solutions. Therefore GS gathered feedback directly from villages and its staff aimed at winning the trust of locals. Extensive community involvement is a key element of GS, also including training and employment of young rural people (Kamal 2012). First, GS used Grameen Bank's existing customer network and hence targeted Grameen Bank borrowers as they were familiar with Grameen and already could build up trust in the company. Moreover, due to their microloan experience these customers were expected to handle repayments properly.[68]

The main asset of GS has always been its highly dedicated and competent staff. It is very important for GS employees not to disappoint a customer and to keep good reputation and also to act as a “social engineer” by bringing energy and social and economic development to rural Bangladesh (Kamal 2012).

Another principle of GS is to provide quality products (ensured by strict quality control) at best price and to offer reliable entrepreneur-based after sales service. This shall be achieved by cooperation with engineering institutes, own production and bargaining with suppliers. REN solutions have to be cost-effective in contrast to traditional energy sources in order to make them attractive to rural people. Qualitative products and prompt response in case of problems are further essential aspects to assure the trust of rural clients. Some developing countries follow a fee-for-service model which is subsidized by governments to provide REN technologies to end-users at low price. GS in contrast chose a sustainable approach, which allows the clients to become owners after full re-payment and to use eg SHS up to 25 years. GS aims at providing innovative financing schemes which make REN technologies affordable and cost-effective. The economic viability of a product is evaluated by GS through conducting feasibility and break-even analysis leading to realistic targets and minimized operating costs (Wimmer 2012; Kamal 2012).

Moreover, GS always aimed at linking REN technologies with local capacity development and income generation in order to follow a sustainable optimized approach (Kamal 2012).

GS was successful by starting off first focusing on one technology with modest funding and a small office, followed by slow expansion, steady improvement, innovation and keeping organizational costs at a minimum. The renowned name of

[68] Information provided by GS headquarters (Mr. Rabbi) on 6 March 2013

its affiliate "Grameen Bank" could be used as valuable asset, however GS had to prove not to disappoint customers in order not to obtain negative reputation. By the year 2000 GS reached break-even and has been generating a modest yearly profit since then. In 2010 GS operated 1,000 field offices, opened one new branch a day, employed 9,000 field staff and reached more than half a million customers. The World Bank stated that in Bangladesh due to access to electricity the income of rural households grew by 20%, poverty rates fell by 15% and the study time for school children increased by 33% (Wimmer 2012). The following table shows main figures and facts of GS operations as per end of 2012:

Table 4: GS – figures and facts (as per: December 2012)[69]

No. of Solar Home Systems (since inception)	1,020,014
No. of Biogas Plants installed (since inception)	24,206
No. of Improved Cooking Stoves (since inception)	595,516
Total Offices	1,493
Branch Offices	1,251
Regional Offices	180
Divisional Offices	16
Grameen Technology Centres	46
Number of districts covered	64 out of 64 districts
Number of upazilas covered	508 upazila
Number of villages covered	50,000 villages
Total employees	11,128
Installed power generation capacity	53.00 MW
Daily power generation capacity	230.00 MWh
Installation of micro-utility systems	Over 3,262 systems
Number of trained technicians	16,388 technicians
Number of trained customers	414,744 users
Full Paid customers (ownership)	249,546 customers
User under maintenance agreement (After 3 Years)	32,011 customers
Green Jobs Creation by 2015	100,000

For 2013 GS set the following plan: sales of SHS: 350,000, sales of biogas plants: 6,000, sales of ICS: 360,000 and formation of 10,000 green jobs.[70] **GS** pursues the

69
http://www.gshakti.org/index.php?option=com_content&view=category&layout=blog&id=54&Itemid=78

following **energy millennium development goals** until 2015: Installing 1.5 mio SHS, constructing 100,000 Biogas plants, producing 5 mio ICS and creating 100,000 green jobs. 2,000 local offices shall be established, 10,000 technicians and entrepreneurs shall be trained, 150 GTCs shall be set up. At least 75 million Bangladeshi shall be empowered by clean energy by 2015. GS also considers to open an International and Technical Assistant Department to ease replication programs for other countires (Kamal 2012).

3.2.4 Structure

GS' operation is geographically divided into zones, divisions, regions and branches. A highly decentralized structure with tight networking and informal joint decision-making is followed. Monthly manager meetings are held in Dhaka, where important topics such as price and wage increase are discussed. GS decided to have branch offices operating as profit centers and hence being responsible for costs, revenues and profit which is deemed to lead to improved results. Head office managers undertake field visits for hiring staff, training people and to monitor equipment (Wimmer 2012).[71] The GS organization chart can be seen in the following figure.

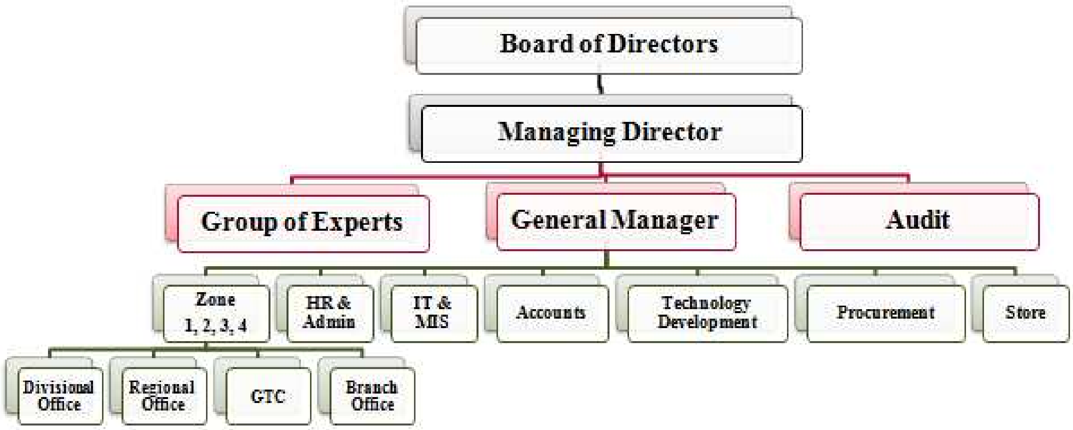

Figure 17: GS organization chart[72]

3.2.5 GS and Grameen Shakti Social Business (GSSB)

GS was established as NGO and hence would not be blamed if it distributes grants for free or loses money. The aim was to create a self-sustaining market-based business and therefore GS intended to form a separate company called Grameen Shakti Social Business (GSSB), which is for-profit, however dividends shall not be

[70] Information provided by GS headquarters in March 2013
[71] Information provided by various GS staff in February and March 2013
[72] Information derived from a power point presentation of GS Managing Director Mr. Kamal (dated Dec. 2012), provided by GS in March 2013

paid but investments shall be returned over a specified period of time (Wimmer 2012). The main objective of a social business is not to maximize profits but to solve a social problem, but being sustainable. Profits shall be reinvested into the company in order to improve and enlarge the business and reach a sustainable long-term solution.[73] In such case, GSSB could receive equity from investors and would be entitled to buy shares. The initial idea was to form GSSB and to use GS for supervision, evaluation, training and R&D. GSSB shall have taken over all operational activities, such as marketing, maintenance, etc (Wimmer 2012). Due to some differing opinions between GS and its funder IDCOL the idea of GSSB could not be executed as initially planned and as described above. However, GSSB has been set up in November 2012 and is currently looking for funds to start off its business. At first the ICS business shall be targeted by GSSB in parallel to GS.[74]

It is deemed that in case goods are provided to poor people for free they might not take care as much of the goods and will less likely re-invest in case of damage, etc. Further, they may even sell them off quickly as they are in need of money. Moreover, local producers may face increased competition which hinders their operations. This concludes that sustainable development cannot be reached in such case. Technology and/or capital transfer to poor people has also to be accompanied with a reliable institutional framework and clear laws. Hence, GS decided to follow a market based business model in which customers become owners and not to offer direct subsidies. This proved to be an efficient model by motivating communities to get involved, training poor people, having women participate, etc. and finally leading to income generation and self-organization of clients (Weimar 2010).

3.2.6 Branches

When opening a new branch GS is searching for an energetic, young, trustworthy, networking staff who is experienced in technology, marketing, accounting, reporting, staff motivation and financing. Afterwards logistics have to be organized, staff has to be built up and office material, such as receipt book, customer installment card, etc. and working tools, such as screw drivers, hammer, drill, etc. have to be arranged for. At the beginning 70% of work comprises marketing and in general 2/3 of the costs arise due to salaries, travel and rent (Wimmer 2012). The storage room of a branch office holds about 100% of a month's turnover for panels and lamps (as they are imported and therefore less easily available than local products) and about 50%

[73] http://www.yunussb.com/
[74] Information provided by GS headquarters (Mr. Rabbi) on 6 March 2013

to 60% of charge controllers and 100% of charge controller components (which are also imported).[75]

When investing into a new branch office various cost factors have to be considered, eg one-time costs such as office furniture and equipment (eg computers), which may amount to 100,000 Tk. The operating costs include salaries, which eg account for about 19,000 Tk per month for a Branch Manager, 10,000 Tk per month for a Field Assistant and 7,500 Tk per month for a local technician. Further, bonuses for exceeding sales targets have to be considered. In addition, costs for advertisement (incl. demonstration meetings, etc.), transport and travels (vehicles, fuel), office rent, electricity, office material, postage, photocopies, printing, phone, training expenses shall be calculated.[76]

Special cultural and terrain characteristics have to be taken into account when establishing a new branch. Villages might be dispersed, in difficult terrain and with different local languages, etc. It has to be respected that communities in Bangladesh are clustered according to social ties rather than by location, which shall be considered when thinking of a new branch. Some areas may suffer from natural disasters, seasonal hunger, etc. and therefore need support from the headquarters and other branches (Wimmer 2012).

3.2.7 Staff

GS employs valuable engineers (field assistants) who are able to handle complex problems, design and modify products and train others. The ideal candidate is less than 28 years, is willing to live in rural areas and able to make good presentations. Newly hired employees receive an introductory seminar at the head office and are then sent to a branch where they are introduced to village leaders, etc. and where they have to take on demanding tasks. They are responsible for marketing, system installation, repair services and for collection of installments. All work is reported to the branch office and data is sent to the headquarters after having been entered into a computer. Daily sales figures as well as cash and bank transactions are reported via a web-based software (created by GS), which can also be derived via mobile phones. Related data is computerized in the divisional offices. In addition, customer data is computerized at area offices via offline forms, which are sent to the

[75] Information provided by GS headquarters (Mr. Haque) on 5 March 2013
[76] Information provided by GS headquarters (Mr. Rabbi) on 6 March 2013 and (Mr. Bikash) on 18 March 2013 and by Shariatpur divisional office in March 2013

headquarters in monthly intervals. After approximately 100 SHS being installed another field assistant is employed at a branch. GS asks engineers to sign a 3 years contract to keep them pro-active. Within 6 months after initial 3 years an engineer can become a branch manager. GS aims at moving its staff from branch to branch in certain intervals to assure ongoing education. A branch manager can be promoted to manage a region, which entails supervising 6 to 10 branches and taking care of accounting, controlling, etc. The next step in the career ladder would be being a divisional manager. There were 7 in place in 2008. In addition to engineers young inhabitants of rural villages can become technicians providing support to field assistants (Wimmer 2012). [77]

GS offers training, a secure job, a good team and promotion chances. In case a field assistant exceeds his monthly sales target he receives a cash bonus of eg 500 Tk in case of 8 SHS sold instead of 5 SHS. A monthly sales target of 5 SHS per field assistant has been chosen by GS as this ensures a branch to break-even. Moreover, the company cares for retirement for staff having worked five years for GS and provides gratuity. It also follows a group life insurance as well as a staff welfare fund in case of accidents or illness. Further, GS pays one month basic salary for each of the two Eid festivals in Bangladesh and it considers pay scale raise and allowance for inflation. Thus, the company aims at motivating its employees in many different ways (Wimmer 2012).[78]

GS middle and top engineers not only receive in-house training, but also benefit from training at other institutions within Bangladesh (also undertaken by IDCOL) and abroad, eg at the Asian Institute of Technology, Thailand and Japan. Special programs are also coordinated with the Bangladesh University of Engineering and Technology. The gathered knowledge can then be distributed by those engineers amongst the other technicians (Kamal 2012).[79]

Borrowers need trustworthy persons, above all in cases in which they are illiterate, and they can build confidence more easily with familiar local people. It is important for GS that its staff follows a listening culture and is very close to its customers, eg by performing technology demonstrations or after sales service (Weimar 2010).

[77] Information provided by GS branch office in Sunamgonj (Sylhet division) in February 2013 and by GS headquarters in March 2013
[78] Information provided by GS branch office in Sunamgonj (Sylhet division) in February 2013 and by GS headquarters in March 2013
[79] Information provided by GS branch office in Sunamgonj (Sylhet division) in February 2013

GS has already created more than 15,000 "green jobs" for providing sustainable REN technologies and is currently recruiting about 500 new employees each month (GS n.a.: "Briefs about GS").

3.2.8 Customers

The typical GS client is between 25 and 55 years, belonging to the wealthier rural middle and 50% of its borrowers are farmers. This claims that the average living condition of rural people can be improved by providing REN by use of microcredit. GS might not be able to address the very poor, however models such as the micro-utility model, in which people can share a technology which will be explained later in the paper, can be a solution to reach more people (Weimar 2010).

As mentioned above many of GS' clients are farmers, eg cultivating paddy or fish. Some clients also earn income from transporting passengers with eg electrically driven rickshaws and some also receive money from their relatives working abroad, lots of them staying in the Middle East or Malaysia. The customer's income range varies from approximately 3,000 Tk to 35,000 Tk per month. The average income of a GS customer amounts to about 8,000 to 15,000 Tk per month.[80]

3.2.9 Audit Department

For providing the head office with adequate information an independent auditing division was founded by GS. It created financial and reporting guidelines and is responsible for checking records and accounts. The department undertakes detailed audits every six months. Usually an audit department consists of 3 teams with 2 members each. The audit staff stays 5 to 10 days at a branch office reviewing all registers (cash memos, cash ledger, bank ledger, collection sheets, client ledger, etc.), gathering feedback from employees and customers and discovering weak points and correcting them. In addition, also surprise audits as well as subject matter audits are undertaken throughout the year to review a branch's operation. In case of improper staff behavior this is directed to the headquarters human resource office to take appropriate action. Due to strong monitoring and prompt action the discipline of GS' branch offices is very high. Teamwork and open discussion is promoted within GS to improve operations. For being more efficient and effective GS decided to move the audit department to its divisional offices. Audit reports are sent to the

[80] Information provided by GS staff and customers of Sunamgonj and Shariatpur area in February and March 2013

headquarters where they are reviewed by two auditing managers (each being responsible for 8 divisions). In case of any action to be undertaken after issuance of an audit report the branch manager has to confirm audit compliance to the headquarters. In March 2013 GS counted 90 auditing accountants. In addition to internal audits GS also undergoes external audits once a year. During such audits also some branches are visited by chartered accountants to take samples.[81]

3.2.10 Grameen Technology Centers and R&D

In order to reduce time and cost of transportation, which can be stressful in Bangladesh due to traffic jams, strikes, floods, etc. GS decided to shift production centers to the country-side and to use them also as training centers in 2005. Initially GS replaced defective items with new ones in order to guarantee prompt service. Therewith arising extra costs could be saved after creation of decentralized Grameen Technology Centers (GTCs). GS currently operates 46 GTCs. They are set up and run by women, who are ideally unemployed, widowed or divorced, between 18 and 30 years and show at least 8 years schooling. A job at a GTC leads to self-esteem and recognition by providing title and income. As most of SHS users are women and women can meet each other easily and show interest in community life it is advantageous to have women employed at GTCs (Wimmer 2012).

In order to become a GTC engineer women have to apply at GS's headquarters, which then selects women and allocates them to different regions. Applicants are usually diploma engineers who graduated from poly-technical institutes and hence have 14 years of schooling. GS aims at ensuring a comfortable and safe working and living place for its employees. GTCs usually host 2 (formerly 3) women and are located near or inside an established branch office. Its employees receive usually one month training at the headquarters for production, testing and repair of lamps, DC-DC converters, charge controllers and mobile phone chargers and learn how to repair defect solar panels and re-install them in battery charging stations. Further, they are taught in accounting and administration. The training is free of charge and a travel, food and lodging allowance is provided by GS. After receiving the diploma they receive working tools, such as tool bag, note pad, pencil, etc. for free. In case of new equipment (eg new types of lights) they receive further training which usually takes place at the branch office. GTS employees also support GS with marketing. In addition to the GTC engineers further (eg 3 to 4) technicians are employed at a

[81] Information provided by GS branch office in Sunamgonj (Sylhet division) in February 2013 and by GS headquarters (Audit Department) on 6 March 2013

GTC, who are trained by the GTC engineers. The technicians shall have a minimum of 5 years of schooling. Groups of potential technicians are trained 15 days and have to take an exam afterwards. Dependent on the results technicians will be chosen. Preference is given to the very poor and widowed, etc. persons. The technicians assemble charge controllers, lamp shades and mobile chargers and are paid per unit finished (Wimmer 2012; Kamal 2012; GS n.a.: "Briefs about GS").[82]

Training women and equipping them with material for self-employment is very advantageous for GS as the company can therewith save on additional branch offices in some areas and on related costs, as operating costs of such establishments would be more expensive (Weimar 2010).

The rapidly increasing sales figures of SHS lead to high demand for SHS accessories as well as for repair and maintenance services to guarantee ongoing operation of the equipment. Hence, GTCs are very important to offer above mentioned services at affordable cost and GS helps there trained technicians to sign annual contracts with GS clients for after sales service. Training of GS staff as well as local people is very important to ensure adequate and cost effective after sales service and effective care of systems. GS has already trained more than 1,000 women to gain knowledge on SHS accessory assembly and after sales service. Further, 5,000 rural school children have already been provided with a REN exposure program. In the future the GTCs shall provide support to adapt new REN technologies to Bangladesh's needs and such shall be pilot tested and then commercialized.

GS R&D focuses on development and use of suitable technologies, on proper marketing and distribution, on innovative financial services and on development and local production of accessories, such as charge controllers, lamps, DC-DC converters, mobile phone chargers, etc. GS also started a computer education program in 2000 in order to promote communication technologies among rural people.[83]

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[82] Information provided by the GTC employees of GS branch office in Sunamgonj (Sylhet division) in February 2013

[83] http://www.gshakti.org/index.php?option=com_content&view=section&layout=blog&id=6&Itemid=57

GS also undertakes ongoing R&D on solar irrigation pumps, solar water heaters, solar cookers, solar dryers, solar water purifiers, fiber glass biogas plants, organic fertilizers, wind turbines, forestation and cemented concrete cooking stoves (GS n.a.: "Briefs about GS"). Further, the company started a solar thermal program which provides flat plate and vacuum tube solar water heaters as well as solar and electric hybrid water heaters for domestic and commercial use. Therewith local components shall be used as far as possible. Further, GS follows a tree plantation program as only 17% of the country is covered by forests, which is deemed to be insufficient to protect the land from erosion, floods, landslides and desertification. Hence, GS sells seedlings and plants trees itself. Already 2,500 herbal, fruit and forest trees as well as 3,500 Jatropha trees have been planted by GS (Kamal 2012).

3.2.11 Technologies

3.2.11.1 General

In order to market a technology GS staff discusses monthly kerosene, etc. costs with potential clients, calculates extra income and how many months it would take to repay a loan. For acquiring new customers GS offers tailor-made financing schemes. As mentioned further above the average GS customer earns a rather low income of about 8,000 Tk to 15,000 Tk per month and usually spends a considerable amount of money on kerosene. Considering such fuel savings and also additional income which may be facilitated by investment into a REN system as well as provision of adequate financing schemes, expensive REN technologies can be made affordable.[84] The various credit schemes will be introduced later in this chapter by a separate section.

The most important promotion tool seems to be word-of-mouth. GS talks to community leaders, teachers, etc., publishes advertisements, shows videos and participates in local fairs. Borrowers receive an umbrella with the GS logo during the certificate awarding ceremony taking place after they have fully repaid their loan, which can be used against sun and rain and is also an important marketing tool (Kamal 2012). Further, GS distributes leaflets, brochures and posters and it demonstrates technologies in market places, schools and villages (Barua 2002).

Further, for being successful it is very important that GS adequately trains the clients, listens to them carefully, is helping in case of problems and is collecting

[84] Information provided by various GS staff and GS clients in March 2013

installments and at the same time is maintaining the technology system in order to keep it running. Not only the owners but all users of the respective technologies shall be trained by GS (Kamal 2012).

As businesses respectively households are often too small to generate adequate profit to afford technologies discussed herein **micro-utility models** can be set up, which means that one person is buying a system and sharing it with neighbors on a fee-for-service basis and receiving therewith additional income. Eg the owner of a rural pharmacy can in addition to using a SHS himself also rent one lamp to the neighbor shop, leading to an additional income of eg 6 Tk per day. All people involved can benefit by increasing their income and reducing energy costs. Further, for example farmers can make use of their bio-waste, decrease their energy costs and generate additional income by installing a biogas plant and selling excess gas respectively electricity to their neighbors, who then can profit of healthier and cheaper energy (eg kerosene or wood costs of more than 500 Tk can be replaced by biogas for 300 Tk per month) (Kamal 2012).

The micro-utility model seems to be very promising. However, only one of the GS customers visited in Bangladesh followed the micro-utility model. GS staff informed that many micro-utility entrepreneurs had complained that their neighbors who rented a light overused the system and hence they stopped offering electricity to them.[85]

3.2.11.2 Solar Home Systems (SHS)

3.2.11.2.1 General

As will be shown later in chapter 3.3 of the paper, Bangladesh is a very favorable location for solar installations. PV technology is very well suited for electrifying remote areas, which do not have access to the grid, as it is easy to install. Further, solar systems are also very favorable as they only need little repair and entail low maintenance cost. In order to reach low income households in rural areas GS developed the SHS program. The rural poor can therewith save on fuel costs which they encounter with conventional electricity eg provided by diesel generators, etc. With SHS homes, shops, boats, etc. can be light up, mobile phones can be charged and TVs and radios powered. By offering suitable micro-credits, providing advocacy

[85] Information provided by GS staff in Shariatpur area in March 2013

and effective after sales service and by involving communities GS has proven to be very successful.[86]

3.2.11.2.2 Advantages of SHS

When starting its business GS first had to convince the rural energy starving households of the benefits of the new REN technologies and hence had to create a market for its equipment. There are various advantages entailed in the use of SHS which can be communicated to persuade people to make use of such a technology. As already mentioned before, and which could also be proven by the local survey undertaken, people in Bangladesh often use kerosene lamps (called "Harican") for lighting, which is bad for health due to the smoke produced and hazardous as houses can burn down due to improper use. Such lanterns also blacken the interior of houses. Using a SHS instead can counter all those problems.

By investing into a SHS people can not only face health benefits but also economic advantage. They can save on kerosene and use the money saved therewith to pay back SHS. The review showed that about 3 liters to 10 liters of kerosene can be saved per household per month due to the use of a SHS. The current price of kerosene per liter as of March 2013 amounts to 70 Tk to 80 Tk. Hence, on average about 420 Tk (considering 6 liters kerosene, 70 Tk per liter) can be saved by non-use of kerosene per month. A customer also informed that sometimes sufficient kerosene is not available in the local market and therefore SHS are very advantageous. As the vast majority of people in Bangladesh is living in rural areas and is not connected to the grid some also use diesel generators to power radios, TVs, etc., which is expensive and often therewith required spare parts are not available. One customer interviewed informed that she has access to a diesel generator powered mini-grid, however, related costs are high, namely 160 Tk per month for using electricity for 1 light and 1 mobile charger. Also in such a case by installing a SHS money can be saved. After three years SHS are usually fully paid, clients become owners and can profit from SHS for about 20 years. Operation and maintenance costs entailed are usually very low.

Another advantage of using SHS instead of kerosene lamps is that lights can be used which are much brighter than lanterns. Hence, children can study and women can do housework at night. One household also informed that due to bright lights available at a house neighbors gather there in the evening and hence the social

[86] http://www.gshakti.org/index.php?option=com_content&view=article&id=58&Itemid=62

environment could be improved. Another person mentioned that owning a SHS delivers some positive status in a community. Moreover, due to SHS and provision of lights shopkeepers can work longer hours and can hence earn extra money. Making lights or a TV available by a SHS in eg a grocery shop can improve working conditions and also let people gather and hence also lead to increased sales of the shop owner. The field research showed that GS mainly provides REN technologies to rural households, but also shopkeepers are targeted. Some examples of increased income generation are given in the table below.

Table 5: Examples of increased income generation[87]

SHS Package	Monthly increase in income	Type of Business
20 W: 2 lights	20,000 Tk	pharmacy
40 W: 2 lights, 1 mobile charger	10,000 Tk	grocery shop
40 W: 1 light, 1 fan for chicken	15,000 Tk – 20,000 Tk (monthly income; GS client bought SHS straight away when he started his business)	small chicken farm and construction material business
50 W: 4 lights (1 thereof rented to neighboring tailor shop for 100 Tk per month)	2,000 Tk	restaurant

Moreover, in some areas the public grid is available but households cannot afford the costs encountered with connection to the grid respectively the application process for grid access is taking a long time. The grid connection fees depend inter alia on the number of poles and length of distribution cables and may amount to eg 50,000 Tk to 300,000 Tk for a household. Further many persons interviewed informed that in case of use of the main grid, households often experience load shedding. In all those cases SHS may be an advantageous option. One person interviewed said that owning a SHS entails independence and freedom.

In addition, as communication technologies, such as mobile phones, are being more and more widely used the need for electricity is increasing and the survey showed that especially solar-powered mobile phone chargers are highly demanded by the

[87] Information provided by GS customers of Chikondi Branch (Shariatpur area) in March 2013

population. As already mentioned in the theory part of the paper and also informed by the households interviewed by use of mobile phones time and cost can be saved, business transactions can be eased and contact to relatives and friends living abroad can be enabled. When having a mobile charger at home people do not have to go to shops to re-charge their mobile and can therewith also save time and costs.

Further, as Bangladesh is prone to natural disasters (eg cyclones) during such cases by use of SHS lights, mobile phones, etc. can usually still be used which is deemed to be very important.

SHS can provide reliable and clean electricity also leading to environmental benefits due to decreased use of kerosene, diesel, etc. However, the survey of various households has shown that environmental consciousness is rather low in rural Bangladesh and has so far played a minor role.

The above given shows that there are plenty of benefits entailed in using a SHS. The households reviewed informed that they are very satisfied with their SHS. As mentioned earlier the most effective marketing tool seems to be word-of-mouth. As customers are very satisfied with GS SHS they tell their neighbors, etc. who then also get convinced about the system and hence demand for GS systems rocketed in Bangladesh. In some areas meanwhile not much marketing effort has to be undertaken by GS itself as due to many existing customers, who positively speak about the system, non-users get convinced and they approach GS staff themselves. In case problems arise, those are usually related to the lights (eg circuit in the lamp shade) and batteries used. However, such problems have reported to be resolved by GS staff quickly and also as technologies improve (eg LED lights) GS and its customers face less such issues. As informed by GS staff sometimes problems arise as users are not fully aware of the functioning of a SHS and hence they overuse it and fully discharge batteries, which leads to problems or they complain when they receive low power in case of less sunshine. In such cases GS staff has to clearly explain how SHS shall be operated.

Most of the non-users interviewed informed that they would be very much interested in a SHS, however due to financial problems they could not afford such a system so far. One household informed that they prefer the grid as they also wish to use AC appliances.

GS staff informed that most of the SHS are sold during the summer and festival (especially Eid) season and during the winter and rainy season SHS sales are considerably decreased.[88]

3.2.11.2.3 SHS Technology

GS SHS packages are 12 Volt stand-alone systems. The equipment consists of the PV modules which are mounted onto iron poles, batteries, charge controllers and auxiliaries, such as wiring, fixtures, as well as of lights and frequently a mobile charger. GS sources PV panels (mono- and poly-crystalline; efficiencies of 11% to 12%) from reliable international low cost companies which also care for logistics, training and technical assistance. The quality of the equipment to be used is controlled by IDCOL. Therefore TUV and IEC certificates/test reports of panels are reviewed and other equipment, such as batteries, charge controllers, is tested in local universities. Batteries have always been sourced locally. They have to be treated with special care and each lamp, etc. shall be connected directly with the battery terminal which shall not run empty. A 50 W system can eg provide 4 hours power a day and batteries can supply power for 3 days without being recharged. PV panels and batteries have to be cleaned from dust, etc. In case of proper use the life cycle of a battery is up to 8 to 10 years (in rare cases even 12 years) (Kamal 2012).[89]

GS tries to repair faulty equipment as far as possible. Eg diodes are changed in the junction box of solar panels in Comilla by GS staff. Moreover, GS is currently undertaking research and establishing contacts to local and foreign equipment suppliers to take care of proper recycling of PV panels and batteries after their use. In order to secure sustainable functioning of the systems GS performs free maintenance for 3 years and offers a post-warranty maintenance for 300 Tk per year afterwards. The warranty period for panels is 20 years, for 30-130 AH batteries 5 years (for 18 AH batteries 2 years) and for charge controllers and other parts 3 years. When talking about warranty clients have to be made aware of the fact that GS cannot be made responsible for inherent failure of appliances powered by SHS such as eg TVs.[90]

[88] Information provided by various clients and staff of GS branch office in Sunamgonj (Sylhet division) in February 2013 and in Shariatpur (Dhaka division) in March 2013
[89] Information provided by GS branch office in Sunamgonj (Sylhet division) in February 2013 and by GS SHS leaflet (March 2013) and by GS headquarters (Mr. Haque) on 5 March 2013
[90] Information provided by GS branch office in Sunamgonj (Sylhet division) in February 2013 and by GS SHS leaflet (March 2013) and by GS headquarters (Mr. Haque) on 3 March 2013 and 5 March 2013

For lighting GS uses power-saving LED technology. GS also intended to introduce a very small scale system of 10 W. Initially they faced the problem that the battery price for such a small system was too high and further battery suppliers were only willing to give 2 years of warranty. This could be countered by GS and now battery suppliers agree to 3 years warranty period. Furthermore the lights initially used were very power consuming. However, now LED lights can be used, which need less wattage. All this helps GS to make the sale of very small systems feasible.[91]

In addition,15 W DC fans (formerly 20 W to 30 W) can be acquired by households for a price of about 2,000 Tk to 2,500 Tk. Usually such fans are imported from China. However, GS suggests its customers not to use fans. During summer time a household may want to use a fan for the whole day, however, it could only use it for 4 hours and it would have to sacrifice the use of 3 lamps in order to have sufficient power available for the fan. In case a SHS is overused and the battery is fully discharged frequently, the battery may only function two to three years. Households can purchase 15 W to 20 W black and white TVs (DC) for about 3,000 Tk to 5,000 Tk. Some also modify computers and use them as color TVs, which would cost about 6,000 Tk to 7,000 Tk. The use of TVs is less problematic for a SHS.[92]

When developing proper SHS two important factors had to be considered: First, the design had to be simple in order to make assembly, installation and maintenance, which is often to be undertaken by not highly educated people from villages, effective and feasible. Further, it had to be modular so that field technicians can efficiently repair and maintain SHS (Amin and Langendoen 2012).

In order to follow a very customer friendly approach, GS also offers to take back SHS in case eg a client gets access to the grid (Kamal 2012). In such cases, the used SHS can be re-sold to other customers at a depreciated price. However, then spare parts may have to be added. GS deducts 25% of the initial package price (without service charge) after 1 year use, 20% for the second to fourth year of use and 15% for the fifth year of use of a SHS. The actual amount of SHS returned is very small.[93]

[91] Information provided by GS headquarters (Mr. Haque) on 5 March 2013
[92] Information provided by GS headquarters (Mr. Haque) on 5 March 2013
[93] Information provided by GS headquarters (Mr. Amin) on 7 March 2013

3.2.11.2.4 SHS Sourcing

For the equipment supply GS has various suppliers, who are chosen by the headquarters and afterwards the respective parts are provided from a central warehouse in Comilla to the divisional offices which forward them to the branch offices. Earlier on more than 60% of the panels have been supplied from Kyocera (Japan). They have their own cell production in Japan and small scale modules are assembled in South Korea. Now GS sources its panels also from various other providers, such as Suntec, Solarland, BlueTec, CNPV (all from China), PremierSolar (India), Hooray (Singapore), Canadian Solar (manufacturing in China). The cells are usually produced in Europe. Earlier on also equipment from Q-Cell (Germany) has been used but they stopped their supplies. Very recently also 7 local companies have been established for module/panel production. GS plans to observe the performance of those companies for about one year and afterwards they may source the panels from them. So far panels can be imported to Bangladesh duty free. Panel prices have been decreased from 3-4 USD/W in the past to 2 USD/ W two years ago to currently 1 USD/W. Hence, before the solar panel made of about 60% of a SHS package price, which could be reduced to about 30% due to falling prices. Panels are shipped to Chittagong port (transport by air would be about 10 times higher). Then the panels are taken to Dhaka customs office, which takes about 6 hours and which is paid by the panel supplier.[94]

In order to generate the best output panels should be mounted at an angle between 20° and 30° (23° being the optimum). During the rainy season (May until July) and also during winter there is rather little solar radiation and hence reduced electricity generation, if any. Customers are made aware of this when they buy a system and it is acceptable to them. One option to overcome this shortage is to load their batteries at a branch office which has access to the grid, which is frequently be used by customers. Due to a considerable increase in demand for batteries and also solar panels more suppliers are now available in Bangladesh. Batteries (30 AH-130 AH batteries with a battery load capacity of about 4 to 5 hours) are sourced from local suppliers (eg from Rohimafrooz, Rimso, Ranks, Volvo or Electro). The cost of a 30 AH battery is eg 3,850 Tk and for a 130 AH battery 13,700 Tk. The import tax on batteries is very high, hence locally produced batteries are cheaper. GS is now producing its own de-ionized water to re-fill batteries.[95]

[94] Information provided by GS headquarters (Mr. Haque) on 5 March 2013
[95] Information provided by GS branch office in Sunamgonj (Sylhet division) in February 2013 and by GS headquarters (Mr. Haque) on 5 March 2013

75-80% of the charge controllers are manufactured by GS itself (single components [50-60 parts] are sourced from China; procurement of required components is sometimes difficult) and the rest is purchased from Focus (Japan) or Schneider (France). A GS charge controller costs about 550 Tk, whereas a Schneider charge controller costs eg about 700 Tk to 750 Tk. Dependent on the size of a SHS panel charge controllers with 5 ampere, 8 ampere, 10 ampere, etc are used.[96]

Different types of lights are used by GS, namely tube lights (10 W; from eg Toshiba, Hitachi), CFL (3 W, 5 W, 7 W; from Energypac, NT, Superstar), LED (2.5 W, 3 W; from Schneider) and LED tube (3 W; from Solarland). GS is now favoring LED lamps. With help of energy efficient lights more lights can be used with a system respectively smaller sized panels and batteries can be used for the same amount of lights which leads to a reduction in the overall package prices. Moreover, in case of LED lights the warranty offered by sub-suppliers is 5 years instead of only 1 year for CFL lights. Further, so far GS staff had to perform lots of repair works due to failure of circuits inside the lamp shades of fluorescent lights, which can be avoided in case of LED lights. Therefore, less customer visits are necessary and GS can save costs. In addition, in case of LED lights, if customers use such lights for longer hours than specified by GS it is less problematic for the SHS system, as such lights need less wattage and hence the battery life is less influenced than in the case of normal lamps. Schneider (France) is producing LED lights and charge controllers in India and they formed a joint venture with GS to set up an equipment assembly factory also in Bangladesh by using components from India. This project is expected to start off in about mid of 2013. GS wants to fully focus on LED lights in the future.[97]

In case a SHS gets damaged due to disasters, such as floods, etc branch offices file an application with the headquarters to receive new equipment. The headquarter is then reviewing the case and providing new equipment for free respectively at 50% cost.[98]

Weimar 2010 suggests that when planning supply chain management, GS shall not only consider costs but also environmental impacts and the environmental life cycle of products shall be studied. Eg manufacturing and transport processes as well as

[96] Information provided by GS branch office in Sunamgonj (Sylhet division) in February 2013 and by GS headquarters (Mr. Haque) on 5 March 2013
[97] Information provided by GS branch office in Sunamgonj (Sylhet division) in February 2013 and by GS headquarters (Mr. Haque) on 5 March 2013
[98] Information provided by GS branch office in Sunamgonj (Sylhet division) in February 2013

packaging shall be reviewed and optimized for being environmentally friendly. Re-use where feasible shall be promoted. Fuel use and related CO2 emissions shall be decreased.

3.2.11.2.5 SHS Prices

SHS package prices, which include the equipment, transportation and installation, vary dependent on the panel capacity and types of lights (tube light, LED, etc.) included. The following table shows eg the SHS package prices including LED lights.[99]

Table 6: GS' SHS package price examples (Schneider LED lights) as of Dec. 2012[100]

No.	System Capacity (Watt)	Loads	Equipment supplied by GS	Package price (Tk)
1	20	4 LED lamps of 2.5 W	A 20 W panel, 4 LED lamps, a 30AH battery, a charge controller, switch & relevant accessories	17,000
2	30	2 LED lamps of 2.5 W, 1 LED lamp of 5 W and a black & white TV	A 30 W panel, 2 LED lamps of 2.5 W, 1 LED lamp of 5 W, a 45AH battery, a charge controller, switch & relevant devices	19,000
3	40	4 LED lamps of 2.5 W, 1 LED lamp of 5 W and a black & white TV	A 40 W panel, 4 LED lamps of 2.5 W, 1 LED lamp of 5 W, a 60AH battery, a charge controller, switch & relevant devices	27,000
4	50	7 LED lamps of 2.5 W, 1 LED lamp of 5 W and a black & white TV	A 50 W panel, 7 LED lamps of 2.5 W, 1 LED lamp of 5 W, a 80AH battery, a charge controller, switch & relevant devices	35,500

[99] Information provided by GS SHS leaflet in March 2013
[100] Information provided by GS SHS leaflet and GS headquarters (Mr. Amin) in March 2013

The adequate panel size for a household is derived by GS by the following calculation (eg in case of the above given package no. 4):

Electricity consumption:

7 LED lamps á 2.5 W á 4 hours per day = 70 Wh

1 LED lamp á 5 W á 4 hours per day = 20 Wh

Black & white TV á 20 W á 4 hours per day = 80 Wh

➔ 170 Wh per day

Required panel size:

$$\frac{\text{170 Wh per day (electricity consumption) /}}{\text{(0.60 [system efficiency] x 5 [average sunshine hours per day])}} = \sim 57\ \text{Wp*}$$

*) It has to be noted that GS customers are requested not to use all lights and the TV at the same time. Hence, a 50 Wp system would be adequate in the above given example.[101]

3.2.11.2.6 SHS Statistics

The following figure depicts the development of installations of SHS by GS:

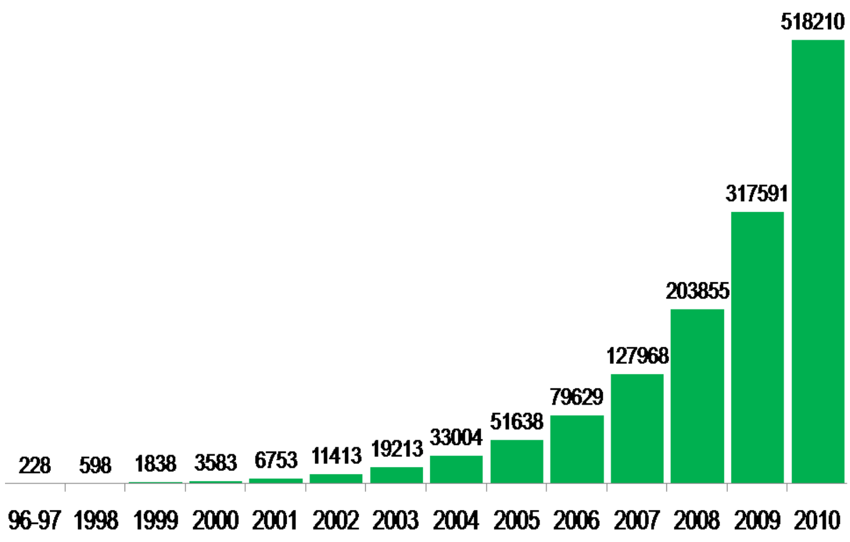

Figure 18: Yearly installation of SHS (cumulative) by GS (1996-2010)[102]

[101] Information provided by GS headquarters (Mr. Haque) on 7 March 2013
[102] http://www.gshakti.org/index.php?option=com_content&view=article&id=58&Itemid=62

3.2.11.2.7 Examples of GS solar systems

Typical examples of GS SHS are given in the table below. GS also started to provide Small Solar Home Systems (SSHS) in the range of 10 and 20 W in order to reach the lowest income households in rural Bangladesh (Kamal 2012).

Table 7: Examples of GS' SHS[103]

SHS	Appliances used[104]	Package price (Tk)	Down Payment (Tk)	Monthly Instalment (Tk)	Monthly Income (Tk)	Purpose
40 Wp	4 LED lights, 1 mobile charger	25,000	3,750	732	5,000	mobile charger, education
50Wp	4 lights, 1 mobile charger, 1 fan (sometimes use of 1 black & white TV instead)	27,800	4,170	814	17,229	education, mobile charger, kerosene savings (6 l per month)
65 Wp	4 lights, (tv and mobile charger connection not used)	33,150	4,973	971	18,000	improved health (no smoke/ blackening)
65 Wp	5 lights, 1 mobile charger	34,000	5,100	995	40,000	no load shedding, education, kerosene savings (8 l per month)

GS has also conducted larger solar installations, eg to power 4 Grameen Phone towers in Noakhali, Sunamganj and Sandeep (6.5 kW each) as well as a solar pump in Naogaon district, which lifts 350,000 m³ water per day for irrigation purpose and a 6.24 kW solar system to power 80 lamps in Comilla. Further 18 larger scale PV systems have been installed by GS in cities (GS n.a.: "Briefs about GS").

3.2.11.3 Biogas, Organic Fertilizers

3.2.11.3.1 General

GS has successfully introduced a biogas program in 2005 and estimates Bangladesh's biogas potential to 4 million plants. The success factors are provision of adequate micro-loans making biogas plants affordable, training of GS staff, local people and users, consultation with clients on plant design and construction, free

[103] Information provided by clients and staff of GS branch in Sunamgonj (Sylhet division) in February 2013
[104] If necessary, GS clients use appliances alternately (not at the same time), SHS packages are designed in a way that clients can use appliances approximately 4 hours per day

monthly after sales service for 2 to 3 years and optional annual maintenance for a small fee after the end of the warranty period as well as linking the technology to livestock and agricultural business.[105]

3.2.11.3.2 Advantages of Biogas plants

As only very few people in Bangladesh can use natural gas from pipelines, most of the people use biomass, such as wood, crop residues, animal dung, etc. as cooking fuel, which leads to deforestation, soil erosion, etc. People have to invest time to collect the fuel and are negatively affected by indoor air pollution, such as smoke. Biogas can tackle this problem by offering clean, efficient energy for cooking, but also for lighting, etc. Further, waste management can be handled more sustainably as wastes can be transformed into biogas.[106] Biogas can continuously be produced by digestion of organic waste, such as cow dung, poultry litter or crop wastes, during which bacteria and viruses are destroyed. Therewith health respectively sanitation conditions can be improved, bad odor can be decreased and less mosquitoes are attracted. GS is currently also studying the possibility of community latrine-based biogas plants. Thus, the biogas can provide a clean environment, saves on firewood and time spent on cooking can be reduced. Due to the usage of the slurry as organic fertilizer also a contribution to food security can be achieved as agricultural business can be boosted (Wimmer 2012; Kamal 2012).

3.2.11.3.3 GS Biogas Technology and Sourcing

Biogas plants can be used to produce gas for cooking and for generators to produce electricity. As already presented in the theory part of the paper different technologies, namely floating dome and fixed-dome models, etc. can be used. After having started with a floating drum digester, GS developed its own fixed-dome model consisting of a special underground tank made of brick, sand, cement and brick chips. This type shows an efficiency of about 80%-90% (due to some gas leakage; 0.037 micrometer pores) and is expected to last 25 to 30 years. Eg such a 3m³ biogas plant can produce gas for 6 to 8 hours powering a cooking stove. In order to improve its product GS started to produce fiberglass biogas plants. This is deemed to be a very promising technology as a fiberglass biogas plant can be easily transported and quickly installed (within 1 day instead of 10 to 15 days in case of the brick-cement plants), even during the rainy season. Fiberglass plants are pre-fabricated and portable, very efficient (as they do not show any gas leakage) and are supposed to least 50 years. They can also rather easily be removed after having

[105] http://www.gshakti.org/index.php?option=com_content&view=article&id=60&Itemid=64
[106] http://www.gshakti.org/index.php?option=com_content&view=article&id=60&Itemid=64

been installed at a certain place, which may be useful, eg in case GS may want to take it back due to non-payment, etc. Dependent on the individual customer's needs, whether a biogas plant shall be used to produce gas only for cooking or also for lighting or for electricity generation in general, GS staff discusses possibilities with its clients and provides advice. So far, GS installed 62 fiberglass biogas plants (10 sourced from China, 50 sourced from a GS co-operation agreement [please see below] and 2 sourced from other local suppliers; 2.2 m^3 gas capacity each). The technology has been derived from China. Now such plants are produced within Bangladesh, however fiber glass has to be sourced from abroad and a high import duty is applicable. Fiberglass is also available in Bangladesh, however this is used for other production purposes. One local company which sources fiber glass from Bahrain has signed a co-operation agreement with GS to produce 50 fiberglass biogas plants in Bangladesh.[107]

A usually underground cistern is filled with typically poultry litter or cow dung mixed with water (at a ratio of 1:2 in case of poultry litter and 1:1 in case of cow dung). For producing the same amount of m^3 of gas eg 50 kg cow dung or 25 kg poultry litter would be needed. In case of eg cow dung the dung is kept for about 2 to 3 days in open space to pre-digest before it is filled into the biogas plant. The rotting mixture then produces gas by help of bacteria and absence of oxygen, which is flowing through a pipe controlled via a valve. The gas produced consists of 60%-70% methane (CH4) and 28%-38% CO_2, 0.02%-0.04% O_2, 0.1%-0.2% H_2S, 2%-3% H_2 and 1%-2% N_2. Hydrosulfide is formed which is corrosive for the equipment and shall hence be removed which can be undertaken by use of peroxide. The optimum temperature range of the digester is 28°C to 38°C, which can usually be kept in Bangladesh’s tropical respectively sub-tropical climate as the digesters are underneath the soil and there is not much variation of temperature throughout the year. However, sometimes during winter time temperatures in the digester fall to about 23°C to 25°C and then gas production is reduced. The hydraulic retention time is between 25 to 45 days. The remainder can be used as fertilizer for farming. As it consists of about 85% of water it shall be dried in order to make it commercially sellable. Very strict rules have been set by the Bangladesh government concerning fertilizers, which have to be obeyed. GS formed memorandums of understanding

[107] Information provided by GS headquarters (Mr. MS Islam and Mr. MA Gofran) on 25 February 2013 and 5 March 2013 and 6 March 2013 and by GS Divisional office in Shariatpur (Mr. MD Jalal) on 11 March 2013

with two companies for sale of the fertilizer (Islam 2007).[108] The following figure depicts the layout of a GS brick-cement biogas installation.

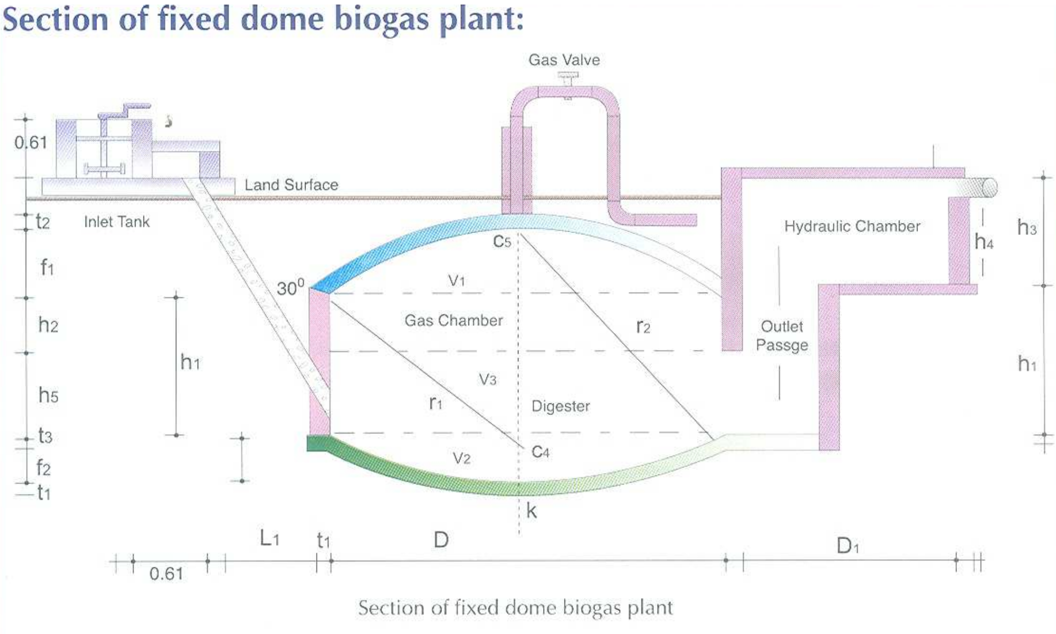

Figure 19: GS' fixed dome biogas plant layout (Islam 2007)

3.2.11.3.4 GS Organic Fertilizer

As described above, a very positive factor of biogas plants is that organic fertilizers can be produced therewith. GS has commercialized its "Jaibo Shar" (Organic Fertilizer) program in 2008, which helps to reduce soil erosion, soil acidity and water losses and therefore supports growing vegetables, etc. Chemical fertilizers, which have been heavily imported, can be saved (up to 50%), farmers can save costs of waste disposal, and it is also used for other purposes like feeding fish. Two dealers are used to take care of GS bio slurry collection, storage, drying, grinding, sieving, packing and distributing (Wimmer 2012; Kamal 2012). GS is providing technical assistance and ensuring quality control. Organic Fertilizers can safeguard nitrogen, phosphorous, potassium, etc. Fertilizers produced from poultry litter are especially suited to reduce soil acidity and aluminum poisoning. Environmental friendly, high quality organic fertilizers are very important in a country like Bangladesh where agriculture plays a significant role. Eg a 3 m³ biogas plant fed with cow dung can produce more than 8,000 kg of organic fertilizer. This slurry can generate income for a dealer in the amount of minimum 2 Tk per kg.[109]

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[108] Information provided by GS headquarters (Mr. MS Islam and Mr. MA Gofran) on 25 February 2013 and by (Mr. Haque) on 3 February 2013 and by a client of Kazikandi village (Shariatpur area) on 10 March 2013

[109] http://www.gshakti.org/index.php?option=com_content&view=article&id=61&Itemid=65

3.2.11.3.5 GS Biogas Prices

GS provides brick-cement biogas digesters (GS model and IDCOL model, which are very similar) with a capacity of 1.2 m³, 1.6 m³, 2.0 m³, 2.4 m³, 3.2 m³ and 4.8 m³ gas.[110] The size and cost of the biogas plants are presented in the following table.

Table 8: Size and Cost of GS' biogas plants[111]

Size (m³)	Operational hours per day	Cow dung requ. per day (kg)	Poultry littler required per day (kg)	Approx. constr. cost (Tk)	Techn. and superv. fees (Tk)	Maintenance fees (Tk)	Total cost (Tk)	Subsidy amount (Tk)	Down paym. (Tk)	Monthly installm. (Tk)
1.6	3-4	43	23	20,000	5,000	700	25,700	9,000	2,505	686
2.0	4-5	54	28	23,000	5,000	700	28,700	9,000	2,955	809
2.4	5-6	65	34	27,000	5,000	700	32,700	9,000	3,555	974
3.2	7-8	87	45	35,000	5,000	700	40,700	9,000	4755	1302
4.8	10-12	130	68	42,000	5,000	700	47,700	9,000	5,805	1,590

GS clients can choose between two options:

1) Customers can build their plant with own funds under supervision of GS. In such case, GS will charge 10% of the total construction cost as supervision fee. In case of the IDCOL model the supervision charge amounts to 5,700 Tk.
2) Clients buy a biogas plant and re-pay it within 24 month (Please note: The detailed payment schedule for SHS, biogas and ICS is provided in a separate section of this paper). For the IDCOL plant clients receive 9,000 Tk subsidy.

The price for fiberglass biogas plants previously amounted to 70,000 Tk due to high quality fiberglass and has been subsidized by GS by 35,000 Tk leading to a sales price of 35,000 Tk. In the future GS expects lower prices for fiberglass biogas plants (without use of subsidies) as GS will call for open tenders.[112]

3.2.11.3.6 GS Biogas Statistics

GS could considerably increase its biogas sales figure since the program's start. The yearly biogas plant construction performed by GS between 2005 and 2010 is shown in the figure below:

[110] Information provided by GS headquarters (Mr. MS Islam and Mr. MA Gofran) on 25 February 2013 and by GS Biogas Program leaflet (March 2013)
[111] Information provided by GS Biogas Program leaflet (March 2013)
[112] Information provided by GS headquarters (Mr. MA Gofran) on 6 March 2013 and by GS Biogas Program leaflet (March 2013)

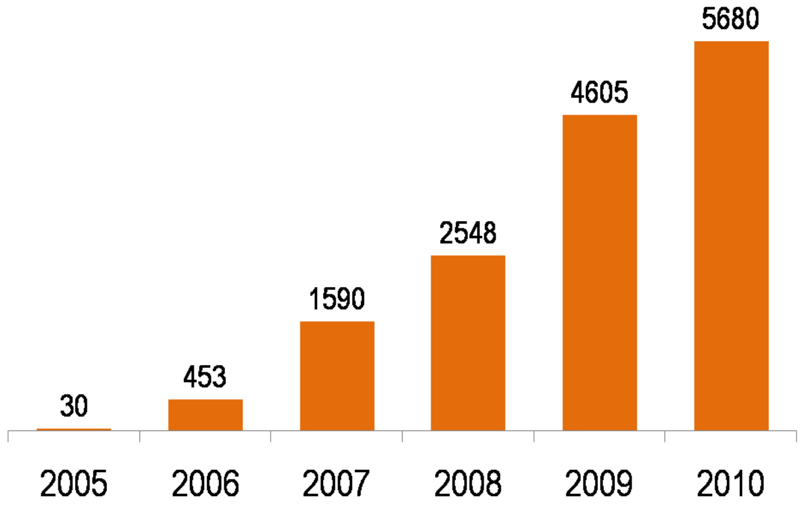

Figure 20: Yearwise Biogas Plant Construction Growth (2005-2010)[113]

3.2.11.3.7 Examples of GS Biogas plants

Various biogas customers have been interviewed. One household informed that a 3.2 m³ brick/cement biogas plant has been purchased. The total package price including service charge amounted to 42,354 Tk (down payment: 5,262 Tk, monthly installment: 1,400 Tk, repayment period: 2 years). The household formerly had 15 cows and could use 90 kg cow dung per day. As some cows died, the household now possesses 10 cows[114] and can hence use 60 kg of cow dung. The 60 kg cow dung are mixed with 60 liters of water from a deep well and filled into the biogas plant which is rather time consuming as it takes about 1 to 2 hours a day. The gas produced can be used for 1 to 2 hours cooking a day. The household has to serve about 13 people. 2 hours of cooking may at times not be sufficient to serve all the people and therefore also an ICS as well as sometimes a "Chula"(traditional stove) is used. Due to the biogas installation and the ICS the household can save 15 t per month on fuel wood and can effectively make use of the cow dung and can hence generate clean fuel for two stoves leading to an improved living environment. The residues of the biogas plant are put onto the owner's rice fields.[115]

[113] http://www.gshakti.org/index.php?option=com_content&view=article&id=60&Itemid=64
[114] Dependent on the type of cow (eg Australian or Bangladeshi breed) different amounts of cow dung will be available; information provided by GS biogas clients in February and March 2013
[115] Information provided by a customer of Sunamgonj branch office (Sylhet division) in February 2013

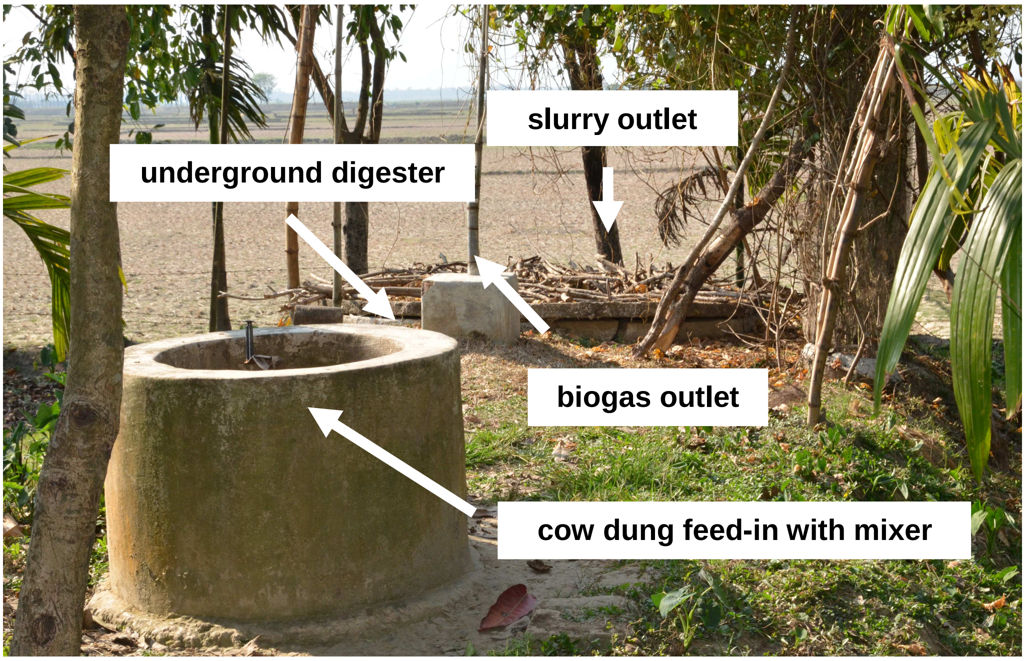

Figure 21: Example of a biogas installation (based on cow dung)[116]

The survey undertaken with various households in Sunamgonj and Shariatpur area showed that as sufficient amount of feedstock is required biogas production is only feasibly for clients possessing abundant cattle respectively poultry. This becomes even more evident in case of associated electricity generation.[117]

Biogas plants used for electricity production are often installed by middle to large size livestock owners. By use of a generator the gas is transformed into electricity. Dependent on plant size and appliances powered, electricity can be made available for 8 to 24 hours a day by a biogas plant. Eg lights, fans, water pumps, computers, etc. can be powered (Kamal 2012). Hence, GS not only supplies households but also installs larger commercial plants, which can produce electricity eg to be used in restaurants, poultry farms, etc. About 200 biogas plants including electricity generation have been set up by GS so far ranging from 500 Watt to 260 kW installations. For such plants diesel is used to start the engines and afterwards 100% biogas is used to generate electricity. Currently about 500 biogas plants are installed by GS monthly (GS n.a.: “Briefs about GS”).[118]

[116] Picture taken by the author in Sunamgonj area (Sylhet division) in February 2013
[117] Information provided by various GS clients of Sunamgonj and Shariatpur area in February and March 2013
[118] Information provided by GS headquarters (Mr. MS Islam) on 5 March 2013

Also micro-entrepreneur biogas installations have been set up with which the owners can serve several clients and earn income. Eg a 9 m³ biogas plant can serve several stoves, 1 mantle lamp, a 2 kW gas-powered generator and a clientele of 13 people, who pay 400 Tk per month each (Wimmer 2012).

GS further promotes an integrated waste management program in urban areas to ensure adequate waste separation into organic and inorganic wastes and proper recycling and conversion into biogas. In Dhaka the daily waste produced amounts to 5,000 tons. Hence, abundant feedstock would be available and the problem of waste disposal could be encountered (Kamal 2012).

GS also examines the production of bottled biogas to be used to power vehicles and small manufacturing units (Kamal 2012).

3.2.11.4 Improved Cooking Stoves (ICS)

3.2.11.4.1 General

Most of the energy which is used in Bangladesh is dedicated to cooking. GS wanted to counter the high demand for biomass fuels and also the indoor air pollution experienced with cooking on traditional stoves and hence started the Improved Cooking Stoves (ICS) program.[119]

3.2.11.4.2 Advantages of ICS

The majority of Bangladesh's population is cooking on traditional "Chula" stoves, which are a simple clay construction built over open fire. They are very inefficient (with efficiency rates of 5-15%) and badly effecting health as they are placed within houses and emitting smoke containing carbon monoxide, particulates, etc. leading to heavy indoor air pollution. Chronic obstructive pulmonary disease, acute respiratory infection, low infant birth weight and cataract are results thereof. Solar cookers have been promoted, but failed as they needed long time to boil water and were not usable in the night respectively during the rainy season. ICS can overcome all those issues. About 50-60% of traditional fuels usually used can be saved therewith and hence forest is conserved, emissions can be lowered and rooms are less blackened, cooking time can be decreased and fire hazards are less likely (Kamal 2012).[120]

[119] http://www.gshakti.org/index.php?option=com_content&view=article&id=59&Itemid=63
[120] Information provided by various staff at GS headquarters in March 2013

3.2.11.4.3 ICS Technology and Sourcing

In 2006 GS started its ICS program by providing stoves made of mud. However, it has been difficult to dry the stoves during the rainy season and also to collect proper mud (GS n.a.: "Briefs about GS"). Moreover it took about one week to install the stove and maintaining of proper dimension during installation has proven to be difficult. Hence, GS aimed at a new stove solution (Kamal 2012). Since 2010 GS provides efficient inexpensive improved cooking stoves made of cement, brick chips and sand, which are ready-made, to be installed in about 1 day, requiring less fuel and therewith save on costs and in addition are much healthier than the traditional option (GS n.a.: "Briefs about GS").[121] In order to show the benefits and to increase demand, GS initially installed some ICS for free. Now GS is participating in local fairs, talking to community leaders and undertaking workshops to inform about the advantages of ICS. It is important to convince the rural people that the ICS fits with the local cooking and eating culture. A further success factor is to make use of locally available materials and fuels and to provide a stove which is easy to use. The stoves provided by GS have a life expectancy of about 2.5 to 3 years. One year after sales service is provided for free (Kamal 2012).

Inter alia GS provides double-mouth ICS with chimney, in which case a flame is produced in the first mouth by fuel input and the second mouth is heated by the hot flue gas from the first. 96 production centers have been established to manufacture the stove components consisting of structure, chimney holder, grate, chimney and cap (Kamal 2012). The ICS show a ground, middle and surface level onto which pots can be placed and have a cast iron grate for firewood in the middle. Ash can easily be removed from the ground. ICS are not yet profitable as the company aims at improving rural health as soon as possible and therefore offers the system at a low price. ICS are usually distributed by help of field assistants, dealers or women entrepreneurs. In case of a dealer, a person can find ICS customers for GS and earn 50 Tk therewith or can also install the ICS which would lead to a total related income of 300 Tk. Women are trained by GS and can then become entrepreneurs by finding new customers and installing systems. They are provided with ICS as a loan-in-kind, which they can sell with a mark-up.[122]

[121] Information provided by GS divisional office in Shariatpur on 11 March 2013
[122] Information provided by GS area manager of Shariatpur on 10 March 2013 and divisional office in Shariatpur on 11 March 2013

Already more than 600 young people have already been trained for being able to sell, construct and repair ICS. Next to commercializing ICS trained technicians can train others and boost the development. Also 10 rural workshops have been opened by GS to manufacture accessories, such as metal grates and chimneys, which are run by entrepreneurs under GS' assistance. Not only rural households, but also restaurants, soap manufacturers, etc. have shown interest in this new stoves as they have proven to be very cost effective by reducing fuel cost by about 50%.[123]

3.2.11.4.4 ICS Prices and ICS Example

According to Kamal 2012 an ICS domestic customer can save on average 250 Tk to 500 Tk a month. The prices of ICS models are given in the following table.

Table 9: Prices of ICS models[124]

ICS model	Domestic ICS	Commercial ICS
Single-mouth	650 Tk	4,000 Tk
Double-mouth (normal)	850 Tk	6,000 Tk
Double-mouth (large)	950 Tk	n.a.

Interviews with various rural households showed that lots of people feel relatively comfortable with the traditional stove as they are used to it and hence do not want to spend their money on alternative improved stoves. However, some could already be convinced of the benefits entailed with ICS and the number of ICS supporters is increasing.[125] The following picture shows a traditional cooking stove as well as the double-mouth ICS provided by GS.

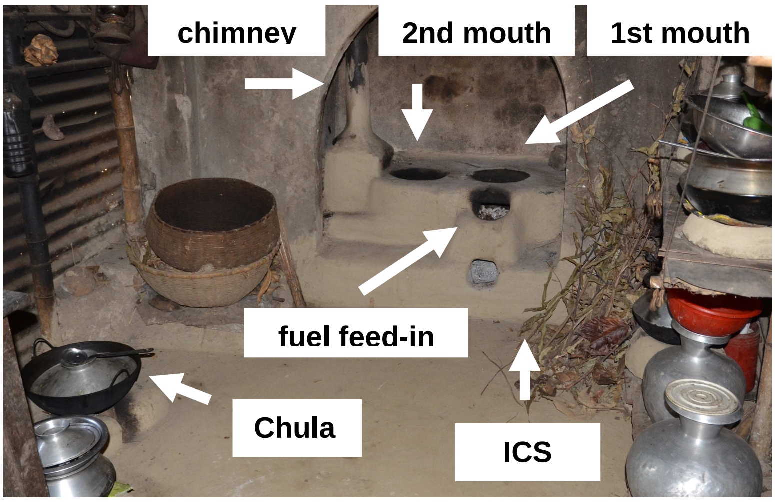

Figure 22: Traditional Chula and ICS[126]

[123] http://www.gshakti.org/index.php?option=com_content&view=article&id=59&Itemid=63
[124] Information provided by GS branch office in Sunamgonj and GS headquarters in February 2013
[125] Information provided by various households in Sunamgonj and Shariatpur area in February and March 2013
[126] Picture taken by the author in Sunamgonj area (Sylhet division) in February 2013

3.2.11.4.5 ICS Statistics

Also in case of the ICS sales boosted, especially up from the year 2010. The following figure depicts the number of ICS installed by GS between 2006 and 2010:

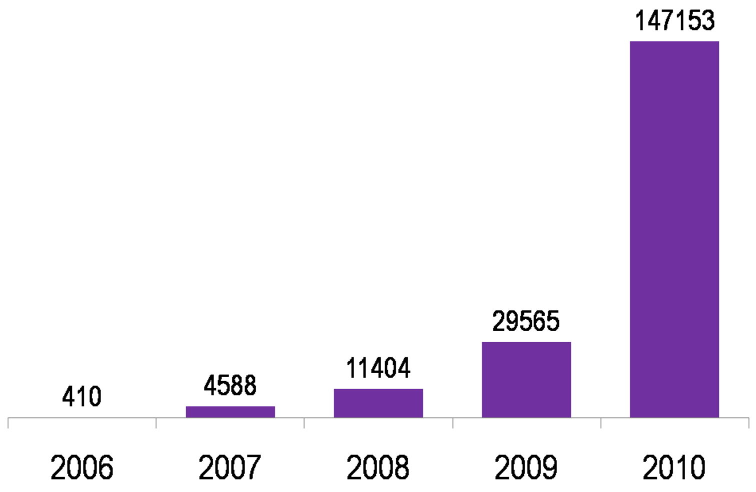

Figure 23: Yearly ICS growth (2006-2010)[127]

3.2.11.5 Wind Power

Use of wind power energy by GS in coastal areas of Bangladesh is under research. 4 hybrid stations, also including diesel generators, have been installed and are powering lights, fans, etc. for cyclone shelters. Further research has to be undertaken in this field for expansion.[128] As operating costs for diesel generators are high and increasing, GS currently examines wind and solar **hybrid systems**. As average wind speeds are insufficient hybrid systems are targeted (Kamal 2012). GS reports about one wind solar hybrid system installed (1.5 kW), which is currently not running due to defective equipment (eg due to a broken blade). It is a 3-blade wind turbine. Equipment has been sourced from the Netherlands. Despite some initial effort to repair the system it is still not operating and as wind conditions are inadequate any further action in this regard has been stopped.[129]

3.2.11.6 GS mini-grid pilot project

GS is also pursuing studies and a pilot project concerning mini-grids. A 2.07 kWp (200-300V, DC) plant has been installed for that purpose. The solar panels have been sourced from JapanSolar (poly-crystalline; 230 Wp panels). The cost for the

[127] http://www.gshakti.org/index.php?option=com_content&view=article&id=59&Itemid=63
[128] http://www.gshakti.org/index.php?option=com_content&view=section&layout=blog&id=10&Itemid=58
[129] Information provided by GS headquarters (Mr. Haque) on 5 March 2013

panels amounted to approximately 248,400 Tk, for the construction (including some cement works due to green field installation) to about 75,000 Tk, for the distribution poles to about 85,000 Tk and for the aluminum cables to about 200,000 Tk (2 x 2 km x 5,000 Tk/100m). Six households are already connected. In total this mini-grid could host 20 households. If enough customers can be attracted the installation may be expanded. Clients connected pay 50 Tk per light per month (Schneider LED 2.5 W each; assumed consumption: 4 hours/day), 60 Tk per TV per month (assumed consumption: 4 hours/day) and 80 Tk per fan per month (assumed consumption: 8 hours/day) as electricity fee. The connection itself is free of charge. In order for being able to make use of the mini-grid, GS sells packages, which include a charge controller, a battery (which can save power for a day), energy efficient lights (2.5 LED) and some also include a fan (DC) or TV connection (DC). A package including eg 2 lights costs 11,100 Tk and one including 4 lights, 1 fan and 1 TV connection costs 25,000 Tk. Packages are sold on credit with the following payment schedule: 30% down payment, 8% service charge (flat) and 48 monthly installments. The mini-grid distribution losses are perceived to be low (about 2% to 3%). One GS staff from the local branch office reviews the mini-grid about once a month to secure proper functioning and is collecting the customer's installments.[130] GS owns this mini-grid and is investigating how it could be sold at a later stage. Later on in this paper a possible investor structure, namely a community REN model, will be presented.

3.2.12 Funds

3.2.12.1 General

When starting the business GS needed financial backing to explore the market, to apply for loans and to pre-finance equipment from abroad. As described further above GS was founded as not-for-profit company and therefore shareholders respectively commercial banks could not be attracted. However, the Rockefeller Brothers Fund and Stichting Gilles Foundation supported GS with USD 75,000 each, the Grameen Fund provided a loan to GS in the amount of 6 million Tk and the Grameen Trust offered 2.5 million Tk for wind energy experiments (Wimmer 2012).

[130] Information provided by GS headquarters (Mr. Mollik Ali) on 7 March 2013 and 18 March 2013

Moreover, in 1998 after submission of a business plan the International Finance Corporation (IFC, funded by the GEF/World Bank) provided a 10 years loan in the amount of USD 750,000 with 2.5% interest rate, a 3 years grace period and a performance incentive saying that for every year of positive pre-tax net income the loan redemption would be reduced by 10%. GS operated very efficiently and finally only had to repay 50% of the loan (Wimmer 2012).

Afterwards the US Development Agency (USAID) aimed at funding GS' growth and provided a grant in the amount of USD 4 million in 2001. In order to have a low-risk financial resource available for years and to reach lasting change GS used this money to establish a revolving fund for 13,000 SHS. As already discussed earlier on in this paper providing grants directly to customers can distort prices, its positive effects may not last, people may sell technologies as they are in need of money. They may not value the technologies that much as they have not paid for them. With further financial means GS could extend the repayment period for its customers from 2 to 3 years and as sales increased economies of scale came into reach (Wimmer 2012).

In addition, the World Bank intended to commercialize the business and provided funding for the Renewable Energy for Rural Economic Development Project (RERED). The outcome was financial support by means of a cash subsidy as well as a loan to IDCOL with 6% interest and technical assistance for 50,000 SHS coordinated by IDCOL and further directed to GS. In 2005 the target could be achieved 3 years ahead and USD 2 million below budget (Wimmer 2012).

Next to the World Bank also DGIS (from the Netherlands) and GTZ and KfW from Germany gave financial support to add 228,000 SHS. In order to keep the business feasible GS follows rigorous bookkeeping and ensures that collected money is transferred to the headquarters as soon as possible (Wimmer 2012).

The figure below provides an overview about GS' funding structure (Weimar 2010).

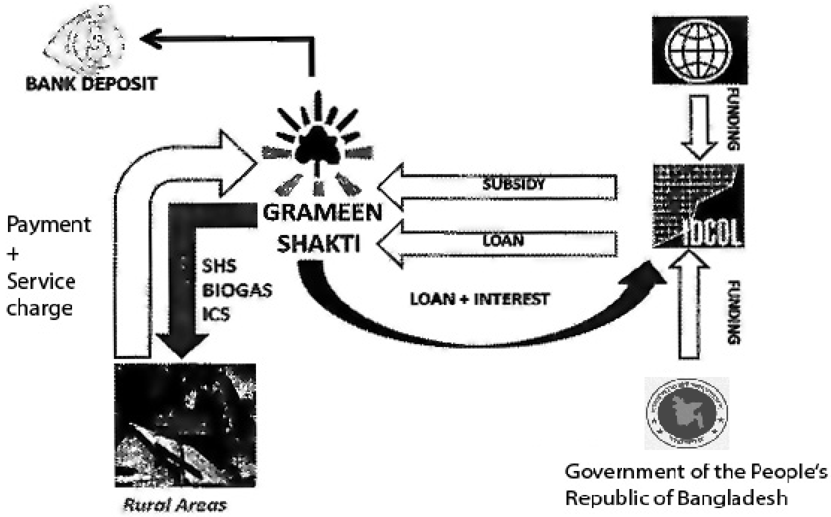

Figure 24: Funding of GS (Weimar 2010)

As of March 2013, about 70% of the prices of all SHS and biogas packages is re-financed by IDCOL and IDCOL also provides a subsidy in the amount of 2,000 Tk for the 20 W SHS as well as 9,000 Tk for the biogas plants. Earlier on 80% of package prices have been re-financed and subsidies have been allocated to all SHS. Further, as will be shown later on in the paper, IDCOL also increased the interest rate for its re-financing service.[131]

It is expected that funds from eg World Bank, ADB or Islamic Development Bank, which can be channeled via IDCOL, may also be addressed in the upcoming three years. However, as subsidies and initially granted loans from IDCOL may cease to exist GS needs alternatives to secure funding. There are several possibilities in this regard. Local banks could be approached. However, they presumably would demand higher and flexible interest rates. Moreover, they would not provide subsidies. Further, it has to be regarded that GS agreed with IDCOL not to take any other source of funding without IDCOL agreement as long as IDCOL is involved. Alternatively product prices respectively service charges could be increased. However, GS faces competition of 45 other REN technology providers in rural Bangladesh and therefore increasing package prices may not be favorable. Package prices may be increased by maximum 5% or 10%. Another option may be

[131] Information provided by GS headquarters (Mr. Rabbi) on 4 March 2013

to address and attract different customer groups, such as larger companies, hotels, supermarkets, governmental institutions, etc. by offering smooth continuous power flow. It is deemed that such new customers would be willing and be able to pay higher prices which could then be used to cover operative costs in rural areas. Moreover, GS could extend its operations and also provide other types respectively medium-sized power plants. GS could also construct mini-grids and borrowers could be encouraged to feed unused excess power into the grid. Moreover, decreased material costs, eg by own or local production could help to further boost business. GS meanwhile has a very good reputation and working organization and is therefore deemed to be successful also without subsidies respectively incentivized loans (Wimmer 2012).[132]

3.2.12.2 Clean Development Mechanism (CDM)

As presented in the theory part of the paper the CDM can also be used to promote REN. GS' programs very well contribute to mitigate climate change. Hence, GS signed its first CDM agreement with the World Bank to take account of its one million SHS installed. Further, GS collaborates with JP Morgan on CDM credits for its ICS. Therewith registration with UNFCCC has already been undertaken. GS also plans a CDM project for its biogas installations (Kamal 2012). PEAR Carbon Offset Initiative Ltd. (Japan) is acting as partner concerning GS biogas and CDM (GS n.a.: "Briefs about GS").[133]

When thinking of SHS, biogas plants and ICS the yearly CO2 savings would be worth USD 3.5 million. However, it has to be considered that the monetary value of such carbon credits varies according to market conditions. The CO2 savings per GS product are depicted in the following table (Wimmer 2012):

Table 10: CO2 emission reduction per product type (Wimmer 2012)

Product Type	Units Installed by 2010	Emission Reduction Per Unit (tCO2/yr)	Emission Reduction Per Product Type (tCO2/yr)	Carbon Finance Equivalent (million US$)
SHS	518,210	0.232	120,224	ca. 1.2
Biogas Plant	14,906	2.08	31,004	ca. 0.3
ICS	192,120	1.04	200,844	ca. 2.0
Total	—	—	**ca. 352,000**	**ca. 3.5**

[132] Information provided by GS headquarters (Mr. Rabbi) on 4 March 2013
[133] Information provided by GS headquarters (Mr. MS Islam) on 25 February 2013

However, emissions which appear during the process of manufacturing (eg of PV panels) have not been taken into account.[134] This may be considered in the future in order to follow a full lifecycle approach.

GS SHS save annually more than 108 liters of kerosene per unit, which accounted for total savings of 64.46 mio USD up to March 2012 (815,528 SHS installed and cost of 1 liter kerosene: 60 Tk; 1 USD = 82 Tk). Concerning biogas plants total savings amounted to 2.43 mio USD up to March 2012 (1.8 tons of biomass annually saved per unit; 22,096 plants installed; cost of 1 ton of biomass: 5,000 Tk). By the use of ICS 25.46 mio USD could be saved up to March 2012 (0.9 tons of biomass annually saved per unit; 463,842 units installed). Hence, GS installations not only are environmentally friendly but also entail economic advantages as they save an abundant amount of money and the country can reduce fuel imports and therefore save foreign reserves (Kamal 2012).

3.2.13 Payment schemes

The main barrier to promote REN next to the principle lack of awareness of REN technologies in the rural areas of Bangladesh were its high upfront costs. As shown further above a GS customer earns on average about 8,000 to 15,000 Tk per month. Innovative financing had to be put in place to make expensive SHS system (eg. 400 USD for a SHS powering two to four small appliances) affordable (Kamal 2012).

GS started off with loans demanding 50% down payment and a repayment period of 6 months, which was changed to 25% down payment and 24 months repayment after some experience. In order to reach more customers GS changed its initial loan scheme and is now offering the following loans (Kamal 2012):

[134] Information provided by GS headquarters on 3 March 2013

Table 11: GS' loan schemes for different technologies (as of March 2013)[135]

Technology	Down payment	Repayment period	Service charge
SHS – 1	15%	36 months	8% (flat rate)
SHS – 2	25%	24 months	6% (flat rate)
SHS – 3	35%	12 months	5% (flat rate)
SHS - 4	100% cash	-	4% discount on package price
SHS – 5 for micro utility (20Wp, 40Wp and 50Wp)	10%	36 months	5% (flat rate)
SHS – 6 for worship places	25%	12 months	none
Biogas - 1	Building plant at own cost under GS supervision, paying half of the supervision fee down and the rest after installation		
Biogas - 2	15% (IDCOL subsidy has to be deducted from total construction cost)	24 months	8 % (flat rate)
Fiberglass Biogas	100%	Upfront cash payment	n.a.
ICS	50%	The second 50% have to be paid at the end of installation	n.a.

The service charge indicated in the table above can be seen as interest rate. In case of GS, not merely a loan is provided like in the case of Grameen Bank but equipment is supplied on credit. Hence, the loan is tied to a commodity and GS is also providing free after sales service during the re-payment period. This may be seen as reason for calling the interest "service charge". As given above the service charge is a flat rate. Application of a declined "interest rate" approach (as undertaken by Grameen Bank) may be considered, as in such case the outstanding amount is reduced by payment of each installment. This would lead to reduced costs for customers and they may be motivated to pay back installments earlier. However, GS staff has to visit customers frequently due to collection of installments and maintenance of the system, which is leading to high cost. In case of Grameen Bank installments are collected weekly at a center meeting and no repair works of equipment, etc. have to be performed. The service charge requested by GS is rather low ranging from 5% to 8% whereas Grameen Bank's average interest for loans amounts to 16%. Hence, a flat service charge as mentioned above is deemed to be

[135] Information provided by GS headquarters and GS SHS, Biogas Program and ICS leaflets (March 2013)

adequate and also necessary to cover costs. GS has to pay 9% (formerly 8%) interest for the re-financing via IDCOL, which applies a declined interest model.[136]

The service charge (flat) and monthly installment is calculated by GS as follows (eg payment option SHS – 1): eg in case of a 30 W SHS with 2 LED lamps, etc. which amounts to 19,000 Tk the **down payment** would be 2,850 Tk (15%), the **service charge** would be 3,876 Tk (19,000 - 2,850 = 16,150 x 0.08 [8%] x 3 [36 months]), the **monthly installments** would be 556.27 TK (16,150 + 3,876 = 20,026 / 36) and **total costs** would amount to 22,876 Tk.[137]

When purchasing REN equipment from GS an agreement is signed between GS and its customer which says that the respective system is bought on credit and GS will remain to be the owner until full re-payment of the system. Two witnesses have to sign this agreement in addition. Usually clients have to undertake the down payment, then the system will be installed and a certain date for payment of monthly installments will be decided upon. Payment of the first installment may already take place two or three weeks after installation of the REN system. If a customer does not pay an installment within a certain month this payment is perceived to be overdue. In case of non-payment of installments for about 5 to 6 months GS may take back SHS systems. Usually in case of financial problems those can be sorted within few months. Sometimes customers are dissatisfied with after-sales service and hence refuse to pay installments. GS then tries to counter-act by improving its service and afterwards payments are usually undertaken as agreed. However, some customers may struggle as they are facing lower income due to various problems with their business or due to illness or dead of the income generating person of a household. If GS customers cannot follow up installments after several months, then they are deemed not being able to pay back a system in full. GS then, as described, can take back a system and can re-sell it to another customer for a reduced price.[138]

Moreover, as another kind of security, if possible, GS staff tries to collect monthly installments in advance. The income of lots of households varies with the season.

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[136] Information provided by GS headquarters (Mr. Rabbi) on 4 March 2013 and (Mr. Amin) on 5 March 2013 and authors own thoughts

[137] Information on the calculation principle provided by GS headquarters (Mr. Amin) on 5 March 2013

[138] Information provided by GS branch office in Sunamgonj (Sylhet division) in February 2013 and by GS headquarters (Mr. Rabbi) on 4 March 2013

Eg a fisherman may have abundant money available in certain months, but much less in others. Hence, he would like to pay more during certain periods of a year and can act accordingly by paying monthly installments in advance. Payment in advance is not only favorable for GS due to the fact of receiving more money at an earlier point in time. It is also advantageous as GS staff may have to visit customers less often as payment of installments is bundled and hence, costs can be saved. GS aims at keeping a good re-payment record as it has agreed that its re-financing institution IDCOL stops its service in case the collection rate of a branch is less than 50%.[139] In January 2013, GS reported a total outstanding loan amount of 8,763,800,000 Tk, due loans (payment is overdue eg 1 month, within the scheduled re-payment period of eg 3 years) in the amount of 300,200,000 Tk and overdue loans (payment is overdue for longer than the 3 years re-payment period) amounting to 136,800,000 Tk. The repayment rate for SHS is usually about 94% and for biogas plants 85%. In case of biogas, customers sometimes face problems with the feedstock (as eg cows of a household die or a poultry farm has to close due to outbreak of a disease), hence they may also experience financial losses, biogas plants cannot be operated and re-payment is delayed. However, as about 97% of GS' sales are related to SHS, the overall repayment rate is rather high. GS informed that its SHS program and biogas program is profitable and the ICS program is deemed to become profitable after receipt of CDM credit, which is already under progress as mentioned before. About 90% of the REN systems are used for household purposes and 10% for different types of shops. In contrast to Grameen Bank's customer structure, GS' REN systems can be purchased by rural as well as urban residents, however, GS' focus also lays on rural customers.[140]

3.2.14 GS replication potential

As shown in the previous sections GS proved to be very successful in promoting REN in rural Bangladesh. A non-profit organization, called "**Global Social Business Partners (GSBP)**" was founded in North America in order to inter alia promote the replication of the GS model. It aims at finding successful MFIs, etc. out of Bangladesh which can be assisted to apply the GS approach. Certain criteria have to be met in order for being able to replicate this model. The solar irradiation has to be adequate in the respective country of undertaking, local suppliers with qualitative equipment shall be accessible and adequately trained engineers have to be

[139] Information provided by GS branch office in Sunamgonj (Sylhet division) in February 2013 and by GS headquarters (Mr. Rabbi) on 4 March 2013
[140] Information provided by GS headquarters (Mr. Reza and Mr. Islam) on 6 March 2013 and (Mr. Bikash) on 18 March 2013

available. GS in Bangladesh can then be visited by the people involved in order to receive detailed know-how, but also the specific cultural and political environment of each location has to be taken into consideration and the model may have to be adapted accordingly. Further, proper sources for funding have to be secured (Amin and Langendoen 2012; for further information visit: http://www.socialbusinesspartners.org/).[141]

The GS model is deemed to be replicable where some income generation takes place. Poor people have to show willingness to improve their life situation and national laws and traditions have to be favorable. When thinking of promoting REN in developing countries research about demand and economic growth potential of the respective region shall be undertaken. Dependent on the location access to and price of raw materials and qualitative equipment, logistical aspects, availability of experts and skilled staff and availability of suitable microfinancing schemes have to be reviewed. National electricity sectors and underlying regulations shall be evaluated (Weimar 2010).

Also Mohammad Yunus says that the GS' business model can be applied in other developing countries. REN technologies work for individuals as well as for communities. Households can produce energy for the grid and can therewith increase income. The importance is to have affordable REN technologies available. Costs can be lowered by further research. Increased use of REN will bring extremely positive impacts to rural development and environment.[142]

GS suggests that in case of replication of the GS model abroad first a small-scale approach shall be followed. Eg 2 staff could review the electricity demand of respective villages and supply of low price equipment has to be secured. After a successful feasibility study eg a 200 SHS pilot project could be focused and adequate funding has to be made available. In general it is important to follow a flexible business model which can be adjusted as needed any time and to make use of lessons learnt. GS could provide eg 1 staff for about 6 months to assist a newly founded rural REN company abroad. Two branch offices could be set up to start off. BOT models could be used as in the case of Grameen Trust, which has been

[141] Information provided by Mrs. Narima Amin (founder and president of GSBP) at GS headquarters on 3 March 2013

[142] http://www.gshakti.org/index.php?option=com_content&view=category&layout=blog&id=52&Itemid=130

introduced earlier in this paper. So far, project proposals for replication have been discussed, eg concerning Liberia and Myanmar, however none has been executed mainly due to lack of funds.[143]

As per Nancy Wimmer, key elements for successful operation of the microfinance plus REN model are establishing a private enterprise and seeking for government support for funding (which may be channeled by especially dedicated institutions such as IDCOL in GS' case), further to secure favorable taxes and feed in tariffs (if any). Moreover, it is very important to place REN engaged staff at rural areas to secure direct and frequent interaction with clients.[144]

3.2.15 Outlook

The following figure depicts a SWOT analysis of GS' business:

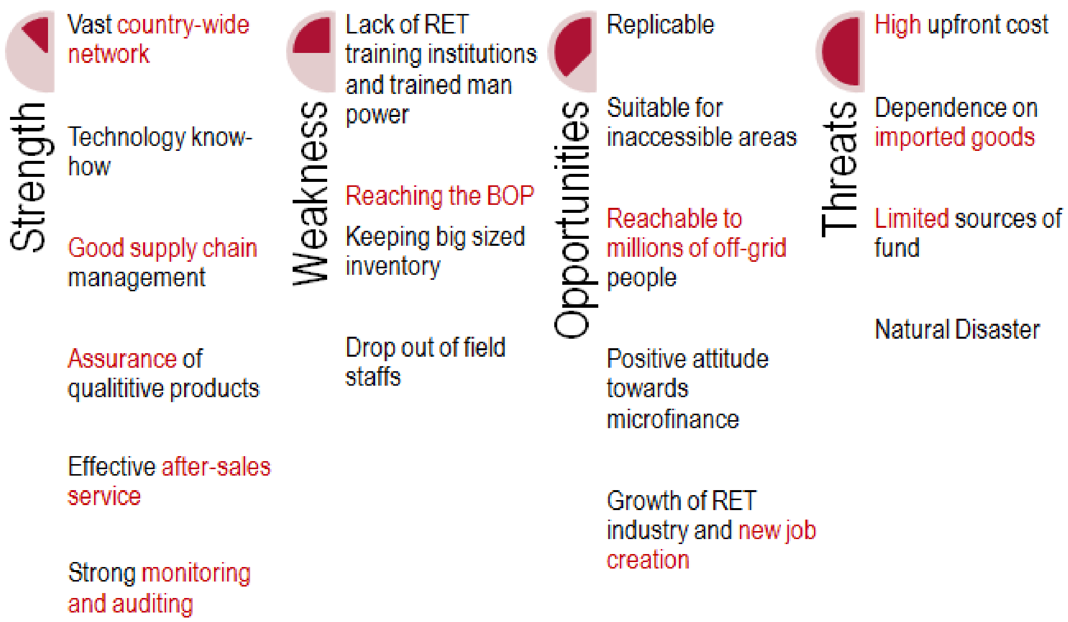

Figure 25: GS SWOT analysis[145]

According to the above given, GS shows various strengths and opportunities, however, in order to stay successful, the mentioned weaknesses and threats have to be properly dealt with.

[143] Information provided by GS headquarters (Mr. Rabbi) on 6 March 2013
[144] Information provided by Mrs. Wimmer (GS author) at GS headquarters on 4 March 2013
[145] Information derived from a power point presentation of GS Managing Director Mr. Kamal (dated Dec. 2012), provided by GS in March 2013

So far the majority of GS' business has been SHS. In the future more focus could also be laid onto larger scale solutions for eg clinics, schools, etc. and mini-grids shall be reviewed which enable to serve whole communities. For such purpose technology upscale, micro-enterprises and hybrid systems can be considered. Therewith proper generation, storage and distribution have to be secured. Technological solutions shall be kept flexible to react according to demand (Wimmer 2012). Later on in this paper it shall be discussed which community mini-grid solutions might be an option for GS and Bangladesh.

3.2.16 Summary

Chapter 3.2 presented the company Grameen Shakti (GS), which is an affiliate of the famous MFI Grameen Bank (GB), which has been shortly introduced at the beginning of the chapter to get a deeper understanding of its operations and to explain GS' background. Muhammad Yunus (Nobel laureate and founder of GB and GS) told that poor people can lift themselves out of poverty if they get access to adequate financial services. They can become entrepreneurs and increase their income. The chapter introduced GBs principles (targeting the bottom poor, forming peer groups, etc.), its organizational structure, its loan programs and other services offered, its financial figures and success indicators. Further, also Grameen Trust, which is assisting to replicate the GB model abroad has been introduced.

Then GS' history (reaching from the first installed SHS in 1996 to 1 million SHS by the end of 2012 and also including biogas plants and ICS into its program) has been presented. GS' goal of providing affordable reliable REN to rural Bangladesh as well as its strategies (including keeping close contact to its customers, employing dedicated competent staff, providing quality products at best price, offering knowledge transfer, creating jobs, etc.) have been introduced. Current figures and facts of the company have been stated, followed by the structure of the company and its idea of establishing a new company in order to guarantee a self-sustainable social business. Afterwards specifics of a GS branch (including approximate costs) as well as its staff (mentioning different job positions and related tasks, educational and training aspects and job incentives) and customers (informing about typical occupations and income levels) have been introduced. Then GS' audit department (explaining the audit organization and process) and Grameen Technology Centers (informing about related staff and their education and training as well as about equipment assembly and also reporting about GS' research and development) have been presented.

Further, the characteristics of GS' technologies, namely SHS, biogas (including organic fertilizers), ICS and also wind energy have been given and GS' mini-grid pilot project has been introduced. Marketing concepts, advantages of GS' REN installations, technologies used, sourcing concepts, prices, statistics and also examples have been shown. Afterwards GS' funding concept (including IDCOL and International Financial Institutions as well as the Clean Development Mechanism) has been explained. Then GS' loan schemes have been illustrated. Finally, GS' replication potential has been discussed and therewith a non-profit organization called Global Social Business Partners (GSBP), which is promoting GS abroad, has been introduced and an outlook for GS has been provided. The next chapter will give an overview about Bangladesh's REN possibilities and may provide ideas for GS' future business.

3.3 Renewable Energy options in Bangladesh

3.3.1 General

The paper showed in the preceding chapters that further investigation in and promotion of REN technologies in Bangladesh should be fostered in order to allow for a sustainable development.

The following pie chart shows that so far concerning REN and related wattage solar energy (20.75 MW) has been exploited most in Bangladesh, followed by biogas (14.18 MW) and wind energy (1.92 MW). Biomass gasification (250 kW) and micro-hydro power (60 kW) have to date played a minor role in installations. Biomass gasification seems to have a good potential, but still has to be further studied (Baten et al. n.a.). This section will provide a more detailed overview of REN possibilities in Bangladesh.

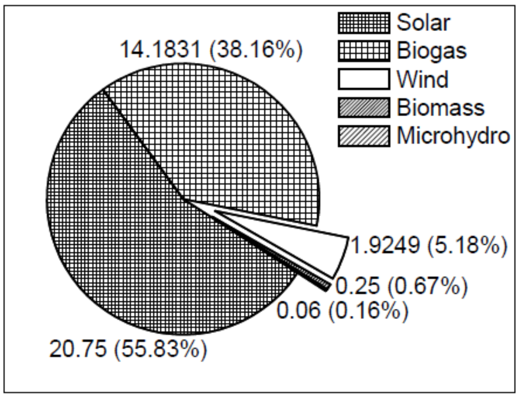

Figure 26: Contribution of different implemented REN technologies in Bangladesh (in terms of installed capacity in MWp, up to July 2009 (Baten et al. n.a.)

Several factors have been restricting REN deployment in Bangladesh in the past, such as high investment cost, lack of technological development and availability as well as site dependency and a missing adequate political and administrative framework. However, Bangladesh is showing abundant REN potential. Especially electricity generation through use of biomass and solar energy is very promising at large in the country and should hence be given priority. Also wind power may be a suitable electricity source in the coastal region such as Patenga, Cox's Bazar, Kuakata, etc. and micro hydro power can be exploited in the Chittagong hill-tracts region (Islam and Khan 2012).

According to Bhowmik, due to Bangladesh's local conditions, the following REN technologies are favorable: various solar and wind systems, micro hydro, biogas plants and electricity generation from rice husks. The potential concerning geothermal sources is rather zero. Mini-grids are very promising to spur rural electrification. The output potential of various REN technologies according to Bhowmik can be seen in the following table.

Table 12: Potential of REN Technologies in Bangladesh (Bhowmik n.a.)

RET	Unit size	Potential number	Total conventional unit
Solar LED based lantern	5W	11 million (below poverty line)	55 MW
Solar LED based lantern + 10W CFL	15W	11million (below poverty line)	165 MW
Solar Home System	30W	12 million	360 MW
Mini grids	12.5W	40011	30000 MW
Mini grid of moderate size			10000 MW
Solar water pumping		225000 (around)	1200 MW
Grid connected PV system			600 MW
Solar PV System		1% area of Bangladesh with 10% efficiency	40000 MW
Rice husk gasifier	200kW	500	100 MW
Micro hydro			1.2 MW (according to BPDB)
Biogas power plants		0.202 million (from poultry waste)	Potential 400 MW Possible generation 100 MW

The following pages will provide further information on the underlying local conditions and technical feasibility of the different REN applications.

3.3.2 Solar Power

The Renewable Energy Research Centre (RERC)[146] of the University of Dhaka with the aid of the United Nations Environment Program (UNEP) and the Global Environment Facility (GEF) collected ground solar radiation data at RERC and seven further meteorological stations in Bangladesh. In addition a 40 km resolution map established from the Climatological Solar Radiation (CSR) model[147] developed by the National Renewable Energy Laboratory of the US and a 10 km resolution map developed by use of satellite images by the German Aerospace Centre (DLR) have been used. The findings are given below (Bhowmik n.a.):

Table 13: Monthly average global horizontal irradiances (GHI), January 2003 - December 2005 (Bhowmik n.a.)

Hours/month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5:30			1	5	17	19	11	7	3			
6:30	3	8	29	66	106	93	86	66	58	46	31	11
7:30	57	93	148	198	252	200	198	180	165	169	157	97
8:30	175	254	318	354	406	321	355	288	303	324	331	237
9:30	300	424	489	521	561	416	438	433	435	473	490	382
10:30	411	573	629	666	681	494	503	514	485	487	580	479
11:30	494	672	712	751	727	532	548	537	485	520	614	498
12:30	518	701	722	764	711	543	570	535	486	488	573	489
13:30	483	646	657	693	641	500	503	482	441	406	510	426
14:30	379	528	541	553	577	451	463	453	385	323	377	309
15:30	236	353	377	402	419	329	372	356	281	208	204	183
16:30	94	175	204	237	257	215	244	231	164	76	57	54
17:30	10	37	55	72	93	93	107	89	45	6	1	2
18:30			2	4	11	17	18	8	1			
Daily average (kWh/m^2-day)	3.16	4.46	4.88	5.28	5.46	4.22	4.42	4.18	3.74	3.53	3.92	3.17

Further, sunshine duration and cloud cover measured by 31 meteorological stations in Bangladesh has been taken into account to estimate radiation values over Bangladesh (Bhowmik n.a.).

[146] RERC is one of the major research organizations of Bangladesh and supervised the largest solar and wind energy assessment project in Bangladesh, the "Solar and Wind Energy Resource Assessment Project" (SWERA); http://maps.nrel.gov/SWERA;

[147] Information on cloud cover, atmospheric water vapor, trace gases and amount of aerosols in the atmosphere are used by this model to calculate the monthly average daily solar irradiation. It is advised to use existing ground measurement stations to validate the data, http://www.nrel.gov/gis/solar_map_development.html

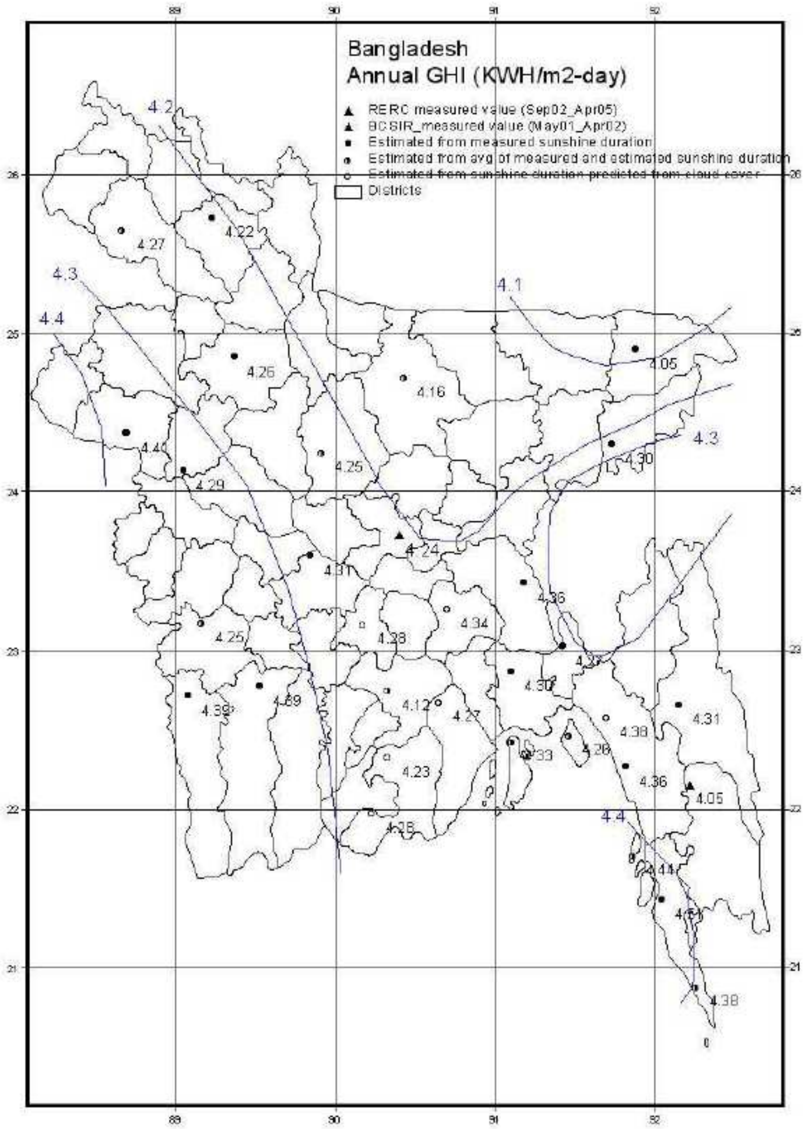

Figure 27: Annual values of GHI for 31 locations in Bangladesh (Bhowmik n.a.)

The final GHI map issued in 2007 showed a monthly average solar global irradiation in Bangladesh of approximately 4.255kWh/m²/day and a diffuse component of solar radiation of about 50%. Hence, non-concentrating PV or thermal collectors would be optimal to use all over the country (Bhowmik n.a.).

Also Rahman 2006, referring to a map jointly prepared by RERC and the National Renewable Energy Laboratory (US), reports a similar irradiation observed of 5 kWh/m2 per day in May and 3 kWh/m2 per day in December. According to Weimar 2010 Bangladesh shows an average of 5 kWh/m2 solar radiation over 300 days per annum. Islam and Khan 2012 report an average solar radiation of between 4 kWh/m² and 6.5 kWh/m² per day, where maximum is recorded in March/April and minimum in December/January. Shiblee 2011 reports the following irradiation at different locations in Bangladesh:

Table 14: Monthly Solar Irradiation at different Locations of Bangladesh (in kWh/m²/day) (Shiblee 2011)

Month	Dhaka	Rajshahi	Sylhet	Bogra	Barishal	Jessore
January	4.03	3.96	4.00	4.01	4.17	4.25
February	4.78	4.47	4.63	4.69	4.81	4.85
March	5.33	5.88	5.20	5.68	5.30	4.50
April	5.71	6.24	5.24	5.87	5.94	6.23
May	5.71	6.17	5.37	6.02	5.75	6.09
June	4.80	5.25	4.53	5.26	4.39	5.12
July	4.41	4.79	4.14	4.34	4.20	4.81
August	4.82	5.16	4.56	4.84	4.42	4.93
September	4.41	4.96	4.07	4.67	4.48	4.57
October	4.61	4.88	4.61	4.65	4.71	4.68
November	4.27	4.42	4.32	4.35	4.35	4.24
December	3.92	3.82	3.85	3.87	3.95	3.97
Average	**4.73**	**5.00**	**4.54**	**4.85**	**4.71**	**4.85**

Hence, by following a conservative approach and using 4.2 kWh/m²/day, an average irradiation of **1533 kWh/m² per annum** can be assumed for Bangladesh.

The average solar radiation in Bangladesh is 200-250 W/m² and the daily average of bright sunshine hours at Dhaka city is minimum 6 hours, which leads to 2190 hours a year (Shiblee 2011).

The best solar irradiation can be found between 15” and 35” latitude north and south. Bangladesh is an optimal country for PV installations as it is located between 20.30 and 26.38 degrees north latitude and 88.04 and 92.44 degrees east (Anam and Al-Bustam 2011; Islam and Khan 2012). Therefore, PV modules shall be oriented towards the south.

In Bangladesh PV panels should optimally be installed at 45° during summer and between 15° and 20° in wintertime as the sun rays fall directly in summer and transversely in winter. As the seasonal adjustment of the PV panel angle is complex, experts recommend to align the panels at 23° to avoid changing the angle and to optimize the orientation towards the sun (Ahammed and Taufiq 2008; Weimar 2010).

The following table provides an overview about the PV market in Bangladesh and shows that large areas of the country are not electrified and SHS bear significant potential in tackling this issue.

Table 15: Projection of Solar PV market in Bangladesh by administrative district; SHSS – SHS_{small}, SHSL – SHS_{large} (Islam and Khan 2012)

Division	Rural House holds in Bangladesh	Total unelectrified Households	Potential SHS Market (Liberal market)		Existing SHS Market (Conservative market)	
			SHSS (1)	SHSL (2)	SHSS (3)	SHSL (4)
Barisal	888,240	778,07 2	361,803	52,133	29,46 9	10,768
Chittagon g	2,416,46 9	1,848,4 55	1,059,1 05	177,45 2	92,13 4	31,708
Dhaka	3,802,67 8	3,274,4 45	1,293,4 06	121,15 4	99,04 5	34,942
Khulna	1,348,90 8	1,096,7 33	470,498	44,966	35,26 8	12,512
Rajshahi	3,436,32 3	3,018,7 67	821,105	81,507	64,20 8	25,300
Sylhet	861,797	717,05 7	261,009	63,101	24,92 6	8,081
Total	12,754,4 15	10,733, 529	4,266,9 86	540,31 1	345,0 50	123,31 1

3.3.3 Biogas

Bangladesh shows a significant biogas potential, as the country's population is very much focused on agriculture. An average village, which is defined by its community as described earlier on in this paper, counts approximately between 100 and 500 households. 70-80% of those possess at least one cattle producing about 8-10 kg manure each day, which can be converted into 0.036m³ of biogas. In addition the households have agricultural side products, such as paddy straw or rice husk available and also lots of water hyacinth can be found in Bangladesh, which can be used to produce biogas (Hasan and Khan n.a.).

Also Baten et al. report that biogas is a viable REN option in Bangladesh as the required raw material, such as rice straw, rice husks or cow dung is widely available. The first biogas plant, a floating drum plant, has been installed in 1972 in the country. Since then 42,211 plants have been built until July 2009, of which GS constructed about 3,664 plants. IDCOL started to promote a new fixed-dome design in 2006 with co-operation of POs, also GS, under the National Domestic Biogas and Manure Program. Therewith already 8,458 plants have been installed. Also power generation plants based on biogas have been constructed, such as a 4 kW and a 7.5 kW plant set up in a poultry farm and a 800 W plant based on cow dung (Baten et al. n.a.).

Investigation showed that out of the above mentioned 42,211 biogas plants only 47 percent are properly functioning and 32 percent are only partly operating due to inadequate maintenance, missing technical knowledge and deviation from quality standards (Baten et al. n.a.).

According to Mahdi et al. the biogas potential is about 5,628 Mm^3/year in Bangladesh. Hence, approximately 4 million biogas plants could be constructed with the feedstock available. However, dissemination rate of such plants is rather low and a study undertaken by Mahdi in the Pabna district, in which 80 biogas plants have been reviewed, reported that 50% of the plants were not functioning and 15% showed interruptions. Failures are due to various reasons, namely technical, constructional, operational, site selection, design, economic failure, etc. The problem perceived therewith is that in case of malfunctioning plants people lose interest in such technologies and they do not properly take care of the equipment (Mahdi et al. n.a.).

Nevertheless, the local conditions in Bangladesh are very favorable for biogas plants. The optimum mesophilic temperature for biogas production is 25 °C to 37 °C, which is frequently observed in Bangladesh. Moreover, 22 million cattle are available in the country, which deliver approximately 220 million kg of dung per day and can produce about $2.97*10^9$ m^3 biogas per year therewith, which equals $1.52*10^6$ tons of kerosene. Further, also poultry litter, human excreta, garbage, water hyacinth, etc. can be used for biogas production (Mahdi et al. n.a.).

Bangladesh applies the Chinese fixed dome biogas plant design and the Indian floating cover design. Lots of people are favoring biogas plants as they are not emitting smoke, are environmentally friendly, do reduce bad smell and contribute to fuel savings and hence reduce cost. Most of the biogas plant owners are relatively well-off and earn around 12,000 Tk per month. When thinking of setting up a biogas plant diverse considerations shall be taken into account. The plant shall be sized properly, which means that it shall consider the daily biogas consumption of a family and the feedstock available. Proper equipment shall be chosen, adequately installed and optimally maintained. The dome of the biogas plant shall be covered with soil to prevent cracking due to gas pressure and the location of the plant shall be close to raw material and water. The slurry by-product can be used as valuable fertilizer or fish feed. Investigations show that slurry sellers can earn 400 Tk per month or even more (Mahdi et al. n.a.).

3.3.4 Biomass Gasification

As stated above, agriculture plays an important role in Bangladesh. Hence, agricultural waste as well as industrial waste, such as rice husk and bagasse from sugar industries are abundant (Hasan 2009). Use of such biomass waste for energy production does not lead to a negative impact on food supply as claimed in case of use of crops as feedstock (Schwaiger 2012).

The following map shows the districts in Bangladesh with rice mill clusters (Bhuiyan 2011):

Figure 28: Rice mill clusters in Bangladesh (Bhuiyan 2011)

The following table shows the yearly rice and sugar cane crop yield in Bangladesh:

Table 16: Rice crop in Bangladesh in million metric tons (BBS 2010)

Year	Rice crop	Sugar cane
2007-2008	28.93	4.98
2008-2009	31.32	5.23
2009-2010	31.98	4.49

The above given information provides evidence that rice husks display a very promising feedstock for gasification. Bangladesh is, with over 100 000 rice mills, a rice focused country. Rice husks show a good calorific value (heating value: 14 MJ per kg) and are carbon neutral (Khurshee-Ul-Islam and Khan n.a.).

Rice husks make of 20% of the rice on average. They can be used directly as fuel or indirectly in case of briquette, which leads to a more efficient feedstock. The briquetting of rice husk is available on commercial basis in Bangladesh, with more than 900 relating machines operating. A survey of 1075 rice mills in Bangladesh conducted in 2005 showed the following results (FAO 2006):

• Milling Capacity (Tons/day) : 18,281.60
• Total rice husks produced from rice (Tons/day) : 47,475.43
• Total consumption of rice husks (Tons/day) : 30,826.04
• Total surplus rice husks (Tons/day): 16,649.39
• Average Price of rice husks (Tk/kg) : 2.20 (TK/Kg)[148]

Also according to Sharif (2009) and as per Khurshee-Ul-Islam and Khan (n.a.) there are about 8 to 9 million metric tons of rice husks annually available in Bangaldesh.

The theoretical potential for rice husks gasification is about half of the above mentioned value (4 million metric tons), as rice husks are also used for domestic cooking, steam production for rice parboiling, etc. This would provide an opportunity for 400 MW of capacity (Bhuiyan 2011).

As rice husks are only abundant during crop seasons, it might be considered to add other biomass, e.g. saw dust, bamboo dust, coconut shell, etc. with certain proportion if needed (Bhuiyan 2011). Whichever feedstock is chosen, the cost of it is a crucial factor for the success of biomass gasification (Salam 2010).

[148] Taka-Euro exchange rate according to the Bangladesh Central Bank as per 2013, January 24: 106.7 Taka = 1 Euro, http://www.bb.org.bd/econdata/exchangerate.php

When thinking of biomass gasification, possible side products and therewith potential additional revenue shall also be considered. Rice husk ash shows a high silica content and low moisture content as paddy is dried to 14% or less before milling. The ash is used in cement and steel industries and it might be used for silica chip manufacturing.[149]

So far, only two rice husk gasification projects (fixed bed downdraft) with an installed capacity of **250 kW** (including three AC generators: 2 x 100 kW and 1 x 50 kW; 220 Volt grid line) and **400 kW** respectively (including two AC generators: 2 x 100 kW; 220 Volt grid line) have been undertaken at **Kapasia** of Gazipur district and at **Chilarong** of Thakurgaon/Bangladesh. Both were financed by IDCOL. In case of the 250 kW plant concessionary loans by IDCOL (with 6% interest rate; in the amount of 30% of the total cost; re-financed by the World Bank) and grants (given by the World Bank; in the amount of 50% of the total cost) were given to the project company Dreams Electrification Project Pvt Ltd (DEPL) which was founded to establish and operate the installation. The remaining 20% of the project cost were equity contribution. The equipment was supplied by Ankur Scientific Energy Technologies Pvt. Ltd (India). Total investment costs (including equipment, land, grid line, etc.) amounted to 25,230,378 Tk.[150] 7 people were operating the plant, filling the plant with rice husks manually. The plant was operated 5 hours per day. 1.4 kg of rice husks could produce 1 kWh of electricity. 300 households, 90 shops, 5 saw mills and several poultry farms were expected to be served with this plant. However, only one of the 100 kW generators has been used. The plant was installed in 2007. Due to lack of demand, as most of the customers used electricity only for a few hours a day, the plant stopped operating and people now use SHS instead. Some initial customers purchased high load appliances, such as a fridge, which could have been used with the electricity from the rice husk gasification plant but cannot be used with SHS. As the number of households is limited in that area (about 400) the demand cannot be sufficiently increased. Other households are too far away. The extension of the transmission line would be too costly and is hence not feasible. IDCOL informed that the following lessons learnt can be derived from the 250 kW pilot project: In case of planning to set up a rice husk gasification plant the area shall be carefully selected and a densely populated area shall be chosen. Moreover, it shall be secured that the project includes some own electricity consumption, eg by a rice

[149] http://www.primaryinfo.com/rice-husk-gasification.htm
[150] At the time of investment the exchange rate amounted to 65 Tk per 1 USD, which leads to a total investment cost of 388,160.- USD (Information provided by IDCOL on 14 March 2013)

mill or a silica production plant which can be attached. In addition, the electricity demand of potential customers has to be analyzed precisely.

Taking all this considerations into account, IDCOL financed a second rice husk gasification plant (400 kW), which is currently being built. In case of this installation a concessionary loan (with 9% interest rate) from IDCOL in the amount of 70% of the total investment cost (re-financed by the World Bank) was given to Sustainable Energy & Agro-resource Ltd (SEAL). 30% of the project cost were equity contribution. This project also includes a precipitated silica plant with an annual production capacity of 918 tons of silica. The silica plant will be consuming 75 kW of the electricity generated by the biomass gasification installation. Further a poultry hatcher (300 kW), thirty irrigation pumps (10 kW each) and various rice mills can be supplied with the electricity produced. The gasifier equipment was supplied by Grains Power (India) and the Silica plant by Orbit India, which is also the EPC constructor of the plant. The genset supplier was Cummins (India). Total investment costs amounted to approximately 91.94 mio Tk.[151] 20 people are expected to operate the plant. Rice husks will be filled semi-automatically 10 hours per day by also using a belt conveyor. 2 kg of rice husk will be transformed to 1 kWh of electricity.

IDCOL estimates the lifetime of the rice husk gasification plants to be up to 20 years. Efficiency of both plants has been assessed to be over 70%. Electricity generated by those plants shall be sold for 7 Tk/kWh (considering a 7% yearly price escalation). IDCOL intends to finance 30 further rice husk gasification plants up to 2016. 400 kW to 500 kW projects will be focused, which shall also include a silica plant. Various project proposals have been submitted. Currently funding (eg from World Bank, etc.) for those projects is screened.[152]

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[151] At the time of investment the exchange rate amounted to 73 Tk per 1 USD, which leads to a total investment cost of approximately 1.26 USD (Information provided by IDCOL on 14 March 2013)

[152] http://www.idcol.org/energyProject.php; Information provided by IDCOL (Mr. MD Rahman) on 14 March 2013

3.3.5 Wind Power

Wind energy has so far not much been deployed in Bangladesh, however, there are some potential sites in the coastal areas, which will be shown on the next pages.

A wind atlas analysis and application program (WAsP) has been used by RERC to predict the wind speed and wind energy density at different heights including 50m height in the coastal part of Bangladesh where adequate wind conditions have been assumed due to earlier studies. The program considers obstacles, roughness and terrain around measuring stations and produces a wind atlas for the area in the size of around 100 km². Further the RISOE National Laboratory of Denmark has performed a wind resource assessment using the Karlsruhe Atmospheric Meso-scale model (KAMM), which uses the upper atmosphere wind speed data as well as satellite information. After combining both results the following map has been drawn (Bhowmik n.a.):

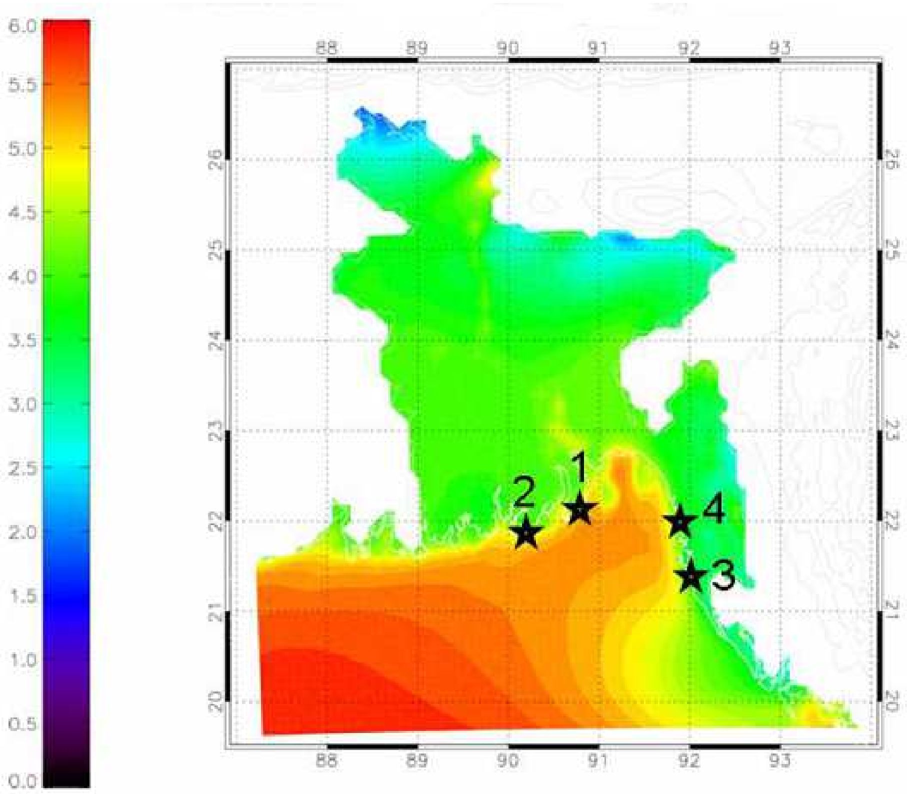

Figure 29: Annual mean simulated wind speed (m/s) at 50m a.g.l. (Bhowmik n.a.)

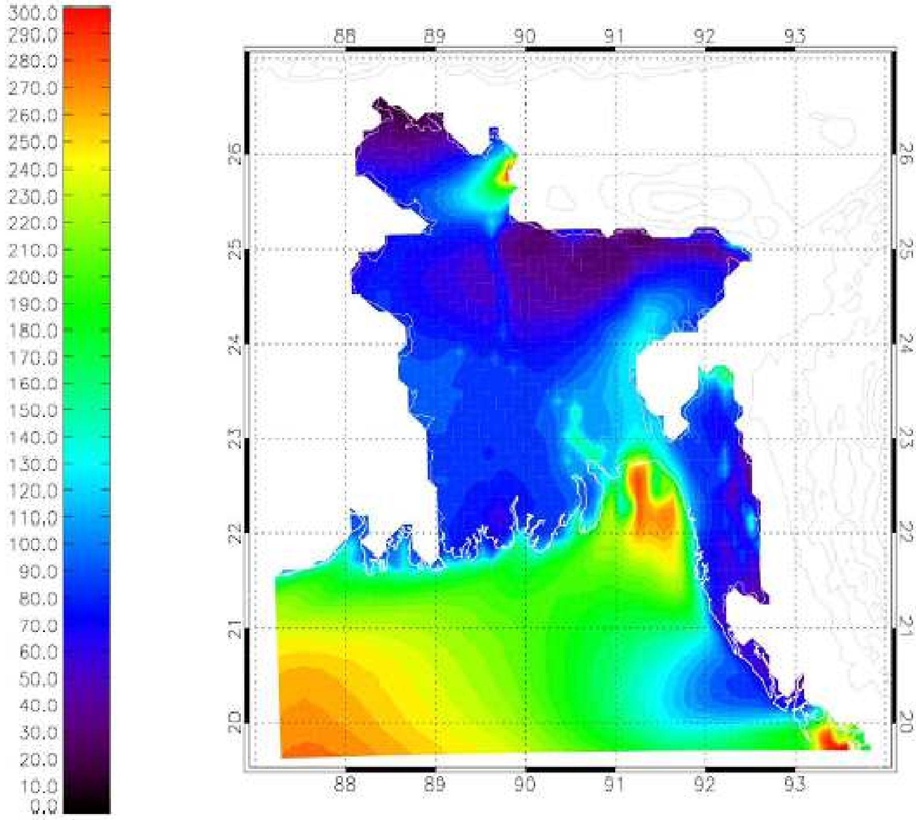

Figure 30: Annual mean simulated wind power density (W/m²) at 50m a.g.l. (Bhowmik n.a.)

The wind measurements show that the most suitable areas are the coastal areas (Bhowmik n.a.). According to Khadem et al. 2005 the wind speed measured in Bangladesh is between 4 m/s and 5.5 m/s at heights between 25 m and 50 m. Islam and Khan 2012 show average wind speeds as in the table given below, measured at 30 m height at three different coastal regions in the South-East of Bangladesh.

Table 17: Monthly average wind speeds measured from 30 m height (Islam and Khan 2012)

Month	Measured Wind speed in Saint Martin at 30m height	Measured Wind speed in Cox's Bazar at 30m height	Measured Wind speed in Patenga at 30m height
January	4.49 ms-1	4.09 ms-1	3.95 ms-1
February	4.62 ms-1	4.17 ms-1	4.02 ms-1
March	4.54 ms-1	3.96 ms-1	3.73 ms-1
April	4.09 ms-1	3.82 ms-1	3.56 ms-1
May	5.37 ms-1	4.79 ms-1	4.23 ms-1
June	6.46 ms-1	5.23 ms-1	4.87 ms-1
July	5.86 ms-1	5.32 ms-1	4.98 ms-1
August	5.98 ms-1	4.93 ms-1	4.39 ms-1
September	4.77 ms-1	4.42 ms-1	4.11 ms-1
October	4.41 ms-1	4.09 ms-1	3.79 ms-1
November	3.83 ms-1	3.81 ms-1	3.63 ms-1
December	4.31 ms-1	4.97 ms-1	3.48 ms-1

Several wind power projects have already been undertaken in Bangladesh. Eg BPDB installed 4 grid connected wind energy units with a capacity of 225 kW each. Another wind park consisting of 50 stand-alone turbines with a rating of 20 kW each was installed on the island Kutubdia by BPDB. Also LGED set up a 10 kW wind-solar hybrid system at Saint Martin's island and a 400 W system at Kuakata beach. Further, GS set up three 1.5 kW and one 10 kW wind-diesel hybrid system for cyclone shelters of Grameen Bank (Baten et al. n.a.). Hence, the above given shows that wind power may be deployed in some coastal areas. However, it by far does not have as high potential as other REN technologies in Bangaldesh for powering rural households at large. Furthermore, concerns have been raised that in the coastal areas tourism is an important income source and wind turbines may distract tourists. Moreover, the Southern coast of Bangladesh is prone to cyclones, hence wind turbines used would need to be very robust and still may frequently be damaged.[153] All such hindrance would need to be overcome to make a wind project successful in this region.

3.3.6 Hydro Power

Bangladesh shows a vast river system. The country is divided into three different landscapes: floodplains (80%), terraces (8%) and hills in the East (12%). The delta of some of the world's greatest rivers, the Ganges, the Brahmaputra and the Meghna, can be found in Bangladesh. On average 1.35 trillion m³ of water flows through Bangladesh each year. During the monsoon season (June-September) flow rates are highest and lowest in wintertime (December-February). The average rainfall in Bangladesh amounts to 2,540 mm. However, due to the flat terrain the country overall shows limited hydro power potential. Nevertheless, there are some suitable sites in the hilly region of Chittagong. For example, in Barkal, which is one of the remote and unelectrified areas in this region with heights ranging from 300-500 m. But also low head sites (eg 2 m head) can be elaborated in case of sufficient discharge (Wazed and Ahmed 2008).

As already mentioned, so far the only major hydro power plant in Bangladesh is the Karnafuly station (located 50 km from the city of Chittagong) with 230 MWel, 5 units (the first one commissioned in 1962 and the last one in 1988). Some other potential large hydro sites and plenty of small hydro sites are under investigation[154] (Wazed and Ahmed 2008). However, India is pursuing projects which divert water for their purpose and hence in case of some rivers less water is reaching Bangladesh, which decreases the hydro power potential as less flow is available.[155]

Islam and Khan 2012 also report hydro potential in the Chittagong hill-tracts, eg from Shovalong waterfall, Shailaprapat waterfall or Kagrachari Toibang Jarna, 26.6 kW, 41.7 kW, 84 kW, etc.

Due to melting snow in the Himalayas and heavy rainfall in Bangladesh, 30% of the country is struggling with frequent floods, which lead to severe damages above all in the agricultural sector and also to heavy erosion of river banks forcing people to resettle. On the other hand, during certain seasons parts of the country face severe droughts. Hence, adequate flood protection and water management is very

[153] Information provided by Ms Kader (GS intern) at GS headquarters in February 2013
[154] http://www.banglapedia.org/httpdocs/HT/K_0098.HTM
[155] Information provided by GS headquarters in February 2013

important in Bangladesh (Huda n.a.). Hydropower can play a significant role in regulating rivers and at the same time provide electricity.

Another important factor to consider in Bangladesh's waters is sedimentation due to high soil erosion rates in the Himalayas and landslides occurring because of earthquakes and heavy rainfall (Huda n.a.). This is significant, as sediments can badly damage hydro power turbines.

The findings show that the hydro potential in Bangladesh is limited to the hilly region in the North-East and South-East of the country. In addition to the before mentioned Karnafuli hydro power station BPDB also established a 50 kW stand-alone micro hydro power plant at Barkal Upazilla Sadar, which uses a natural waterfall. Moreover, LGED set up a 10 kW micro hydro power plant at Bamerchara in Chittagong district (Baten et al. n.a.). Hence, there may be some suitable hydro power sites, however, in contrast to the other REN options hydropower generation faces limits in Bangladesh.

3.3.7 Summary

Chapter 3.3 showed that so far mainly solar energy, followed by biogas, has been exploited in Bangladesh concerning REN. Different factors, such as high investment cost, lack of technology and proper political framework, have until now hindered a large application of REN in the country. However, this chapter clearly showed that the REN potential in Bangladesh is high. Detail figures can be derived from each respective section of the chapter.

Concerning solar power various studies reported that solar irradiation across the country is favourable with an average of about 4.2 kWh/m²/day. Due to the country's location and to follow a simple approach, by not changing the alignment of solar panels throughout the year, the optimum angel for solar panels has been explained to be 23° and panels shall be oriented towards South.

Further, the chapter pointed out that biogas has high potential as Bangladesh is an agriculture based country and sufficient feedstock is available. Cow dung, poultry litter or also agricultural side products, such as paddy straw or water hyacinth, etc are abundant. Also the temperatures in Bangladesh are favourable for biogas production.

Then the chapter indicated that biomass gasification (especially from rice husks) can be another viable source of electricity production in Bangladesh, as plenty of feedstock is available. In case not enough rice husks would available also other biomass such as coconut shell, bamboo dust, etc. could be used in such a plant.

Regarding wind power analysis showed that this is mainly feasible in the coastal areas of Bangladesh (due to the wind speed and wind density available) and in case of micro-hydro some plants could be set up in the hill regions of the North-East and South-East of the country (due to appropriate topography and water flow in those areas), however, in Bangladesh the potential of those technologies for rural electrification is not as big as in case of solar energy, biogas and biomass gasification.

3.4 Community REN model and microfinance (a rice husk gasification example)

3.4.1 General

So far, the paper showed that already many solar home systems as well as small biogas applications have been installed in the country. Moreover, a PV mini-grid pilot project of GS which is supposed to service various households has been presented. However, up till now it is not owned by the rural people but by GS and GS still has to search for potential investors. Further, the chapter before has informed that also other REN technologies could feasibly be exploited in Bangladesh from a technical point of view dependent on the local characteristics. Hence, this chapter will investigate whether microfinance could be used to promote REN technologies on a larger scale (by use of a mini-grid) for eg a whole village by taking rice husk gasification as an example. Therewith microfinance possibilities for larger (mini-grid) projects as well as the application of a rather new technology for Bangladesh, namely gasification, shall be highlighted. As stated before in the paper, two rice husk gasification plants have so far been installed in the country and the related data will be used as base for economic evaluation. About 12 years ago Grameen Bank invested into a biomass gasification plant run on wood branches. Equipment was supplied from India. GS was operating the plant for about 2.5 years. Due to a lack of spare parts the project has been stopped and GS has never followed a biomass gasification project since. However, GS thinks that rice husk gasification may be a viable solution in the future.[156] The technical requirements of a biomass gasification plant have already been presented in a previous chapter. Section 3.4.2 shall provide insights into the economic viability of such a project and section 3.4.3 will introduce a community REN model based on microfinance as funding option.

3.4.2 Economic appraisal, underlying assumptions

Next to technical feasibility as described above also economic viability is a decisive criterion for executing a project successfully and for making it bankable. In order to prove the economic feasibility of a REN project, the following **cost factors** have to be considered: the investment costs, including civil and electromechanical work, land purchase and related administrative costs (eg permission/fees of local

[156] Information provided by GS headquarters (Mr. Haque) on 4 March 2013

authorities) and operating costs. Equipment suppliers should be chosen carefully to secure experienced project managers, prompt successful project execution and reliable and efficient operation. The operating and maintenance costs are deemed to be rather low and stable in Bangladesh, due to low-cost local labour and due to the use of rather simple technology. In order to secure plant availability, the operating staff should be very well trained for being able to react quickly and adequately in case of outage (Ortner 2012).[157]

In order to ensure future viability of a biomass gasification project the **feedstock** (in this case rice husks) availability has to be secured by long-term contracts. The best pre-condition would be a fuel supply contract with fixed prices. Otherwise a price escalation has to be taken into account when calculating a project's value. A favourable scenario would be if the investor(s) into a gasification plant would also be the owner(s) of an adjacent rice mill. In such case, the investor(s) would follow double interest and feedstock supply could be secured. Moreover, considering rice husk gasification close to a rice mill would lead to ecological advantages as the feedstock does not have to be transported over long distances and further the economic operation could be secured as the mill could act as a supplier of biomass and also partly as consumer of electricity (Hasan 2009; Ortner 2012). In case of smaller installations and less feedstock required also dealers collecting rice husks from households, etc. could be engaged. Jobs could be created therewith.[158]

It is assumed that the herein investigated plant is running on average at 80% **load** and the generated electricity is fully utilized. The operating hours are dependent on the demand, the outage time of the plant due to maintenance, etc. and also on seasonal availability of the feedstock, which can in principal be balanced by mixing the feedstock as discussed before with other materials.

The **electricity generated** by a rice husk gasification plant can be sold to private and commercial customers. In the herein given example a 400 kW downdraft fixed bed gasifier project including a mini-grid constructed for electricity distribution shall be screened. This project has been chosen as sufficient data could be derived from IDCOL for such a plant and because lessons learnt from a pilot project have already been considered. As also planned by IDCOL an adjacent silica production plant (75

[157] Information provided by IDCOL (Mr. MD Rahman) on 14 March 2013 and author's own thoughts
[158] Author's own thoughts

kW) shall be served with the electricity produced. Further, next to private households and shops, if existent, a poultry hatchery (300 kW) as well as irrigation pumps (10kW each) and various rice mills in the area could also be powered by the plant. Sometimes dual-fuel engines are used in case of rice husk gasification, running on producer gas and diesel. The herein reviewed project shall merely run on producer gas. Feed In tariffs or other governmental subsidies would be favourable for the project's financial viability, but as there are no such systems available in Bangladesh yet, this has not been considered herein.[159]

To optimize the economics the income generated by sale of **side products** should be considered. The rice husk ash can be used to produce precipitated silica, which is used in rubber, toothpaste and other chemical industries and has so far mainly been imported to Bangladesh. It is deemed that abundant silica clients are available in Bangladesh and hence this can lead to additional income. As the CO2 produced from the gasification process can be used in the silica plant this is also leading to environmental benefits.[160] Due to consideration of an adjacent silica plant also jobs can be created.[161] Further it should be considered that in case of gasification ash, char, tar and waste water is produced. The ash can be used as fertilizer, char can be transformed to be used for cooking and heating as charcoal and tar can be burnt or it can be used as black paint for eg boats. Abundant storage facility for such purpose has to be provided on site (IDCOL n.a.).

It is assumed that 70% of the total project cost is **financed** by IDCOL which is on-lending funds of eg World Bank after successful environmental impact and social assessment analysis. The remaining 30% shall be equity contribution by the owners. The next section of this chapter will discuss a community REN model which could ultimately be used to provide funds from rural households (becoming shareholders via a co-operative) for such a project.

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[159] Information provided by GS headquarters in February 2013 and by IDCOL (Mr. MD Rahman) on 14 March 2013 and author's own thoughts
[160] http://tradetimes.wordpress.com/2009/10/05/bangladesh-goes-india-and-china-way-on-rice-husk-power/
[161] Author's own thoughts

For evaluating the economic feasibility of such a project, a dynamic investment valuation can be conducted by using the **net present value** calculation. By using this criterion the project can be compared with alternative investment possibilities (Kobialka 2011).

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_0$$

NPV	Net Present Value [€]
T	Investment Horizon [y]
t	year-count
Ct	Cash flow in year t [€]
r	risk adjusted discount rate / WACC [1]
C0	Initial investment [€]

The following data shall be considered in the calculation:

Table 18: Overview of the economic data for a 400kW rice husk gasification plant[162]

400 kW – Rice husk gasification plant	
Investment costs	91.94 mio Tk
Cost of spare parts	1st year: 679,500 Tk; 2nd year: 1,019,250 Tk, year 3 to 15: 1,359,000 Tk
WACC*	5%
Investment horizon	15 years (however it is expected that the plant can be operated for 20 years)
Operating hours per year** (30 days outage per year due to maintenance)	3000 h (10 hours/300 days)
Yearly electricity generation (80% load factor)	960,000 kWh
Biomass feed	according to IDCOL for the 400 kW plant on average 2 kg of rice husk is needed for 1kWh electricity produced (in principal 1 kg of rice husks yields about 3 Nm³ of producer gas)
Rice husk costs per year (as per IDCOL the current price for such purpose is 1.5 Tk/kg)	2,880,000 Tk
O & M costs per year (Salaries, etc.)	3,034,730 Tk
Electricity revenue***	7 Tk/kWh
Annual silica production capacity	918 tons

*) The indicated WACC has been assumed under consideration of 30% equity and 70% debt and favourable interest rates expected from the funding financial institutions. (Please note: commercial banks in Bangladesh charge about 15% interest on loans, IDCOL usually charges about 9% and institutions like the World

162 the data given in this table has been derived from Hasan 2009 and from IDCOL office in Dhaka (Mr. MD Rahman) on 14 March 2013 and from IDCOL paper: “Biomass Technologies – Biogas Gasification in Bangladesh”

Bank charge eg 2%. The Corporate tax in Bangladesh for private companies is 37.5% and for public listed companies it is 27.5%.)[163]

**) The 250 kW IDCOL plant has been operated 5 hours per day and due to lack of demand only one of the 100 kW generators has been used. In the calculation herein 10 hours operation time per day (as per the new 400 kW IDCOL plant), 300 days per year with a load factor of 80% leading to an electricity production of 960 MWh per year has been assumed.

***) Electricity customers can save dramatically on kerosene and diesel, which they would usually purchase, by using electricity produced by the rice husk gasification plant. IDCOL charges 7 Tk/kWh in case of its rice husk gasification plants. For the calculation herein the same fee is assumed. According to GS the electricity costs in case of supply by the public grid amounts to about 4 Tk/kWh to 7 Tk/kWh (for households; dependent on demand) and 10 Tk/kW h to 12 Tk/kWh (for commercial entities).[164] Hence, the fee is deemed to be acceptable.

As per Annex 2 and the table below it can be seen that the project (under the mentioned pre-conditions) is very profitable, as full power produced is consumed and additional revenues are generated by the sale of the side product silica. As the net present value is positive, investing into such a plant is financially viable. The net present value is highly dependent on expected fuel costs and electricity price as well as in this case also on silica price development. Also increasing the operation time and the load would have a very positive effect. Operation and maintenance costs are deemed to be and stay low. IDCOL informed that they may re-finance GS in case they intend to set up rice husk gasification projects. Details would have to be discussed.[165] As mentioned before in the paper, proper demand has to be secured and sale of side products shall be considered in order to establish a successful project.

Table 19: Overview of economic appraisal for a 400kW gasification business case

400 kW – Rice husk gasification plant	
Net Present Value	638,429,740 Tk
Annuity	61,507,782 Tk

Maintenance works are, if possible, to be scheduled for late autumn, as the rice harvesting season (dependent on the rice species) is December-January, March-

163 Information provided by GS headquarters (Mr. Bikash) on 18 March 2013
164 Information provided by GS headquarters (Mr. Haque) on 5 March 2013
165 Information provided by IDCOL (Mr. MD Rahman) on 14 March 2013

May and July-August and during this time abundant feedstock is expected.[166] However in principal, as discussed, during times of reduced availability of rice husks additional biomass, like coconut shell, shall be considered for gasification as demand for electricity is expected to be constant throughout the year.

3.4.3 Community REN model and microfinance solution

As described in the literature part of this paper community REN models can be a viable option to make REN projects feasible and to contribute to sustainable development. In the above given case of the biomass gasification project (but also in case of any other REN technology, which is technically feasible in a certain area) rural people of a community could found a for-profit co-op and hence jointly invest into the plant. The main goal of this undertaking shall be to provide funding for a REN installation which can offer cost-effective and reliable REN to as many rural households as possible.

Single households could take out a micro-loan and participate in the REN project by using the loan to acquire a share. After having paid back the micro-loan they fully enjoy part-ownership in the plant. As those households are shareholders they can receive a dividend. In the future they can keep or sell their shares. In addition, if desired, by paying a fee they can receive reliable and cost-effective electricity through a mini-grid installed.

Such community REN projects can also be used as investment possibility for members of the community who want to effectively use their savings. They can become shareholders of the plant and can receive dividend. A specified amount of Taka per share, minimum and maximum amount of shares per person as well as dividend per share and year may be defined. There may also be a differentiation between preferred shares and common shares. All shareholders involved should elect (eg once a year) an executive committee which is representing them and managing the co-op and which in turn selects a chairperson. It has to be secured that the executive committee respectively the chairperson is adequately representing the other shareholders and is not purely following own interests.

The co-op can invest into one or more REN installations including a mini-grid. Dependent on local specifics different REN options may be applied (such as rice

[166] http://www.bpedia.org/C_0376.php

husk gasification, photovoltaic and biogas) and can be used to complement each other in a hybrid approach to spread risk and to guarantee ongoing electricity supply. As a bigger-sized REN project can be facilitated by such a model, equipment and services may be purchased at a better price than in case of smaller single REN installations.

Earnings are received through the sale of electricity via a mini-grid. Electricity can therefore be made available to plenty members of a community and not only to the REN plant owners. This may also be seen as extension of the micro-utility model established by GS, in which a single household installs a REN plant and rents excess electricity to neighbors. Monthly payment of fees by electricity consumers may be conducted through the use of a mobile phone banking system, which may be introduced. Earned profits shall be used to pay dividend to the co-op shareholders, but can also be used to fund community service facilities (such as schools, health care centers, etc.) or to install further respectively extend REN plants, etc. Therewith the co-op could qualify to become a type of "social business" as introduced in the paper before. The shareholder's acceptability of receiving rather low dividend but using profits for community investments (such as schools) instead would have to be assessed.

Grameen Bank could act as intermediary between the co-op and its shareholders and could provide necessary micro-loans and facilitate all financial transactions involved. Grameen Shakti could act as technical consultant and could provide necessary staff to install, operate and maintain the REN system. Potential shareholders can be attracted by Grameen Bank and Grameen Shakti by making use of its vast social network and its good reputation. Mutual strong monitoring of all parties involved and employment of dedicated staff is advised to secure successful operation.

Specific characteristics and requirements of the applicable legal framework for such a community REN project have to be assessed. Eg tax may have to be paid dependant on the co-ops generated profit. Moreover, rent may have to be paid to land-owners in case the REN plant is not built upon the owners land or community land (such as school roof, etc.).[167] The structure of a community REN model as described could look as depicted in the figure below.

[167] author's own thoughts and suggestions including ideas of GS and GB staff

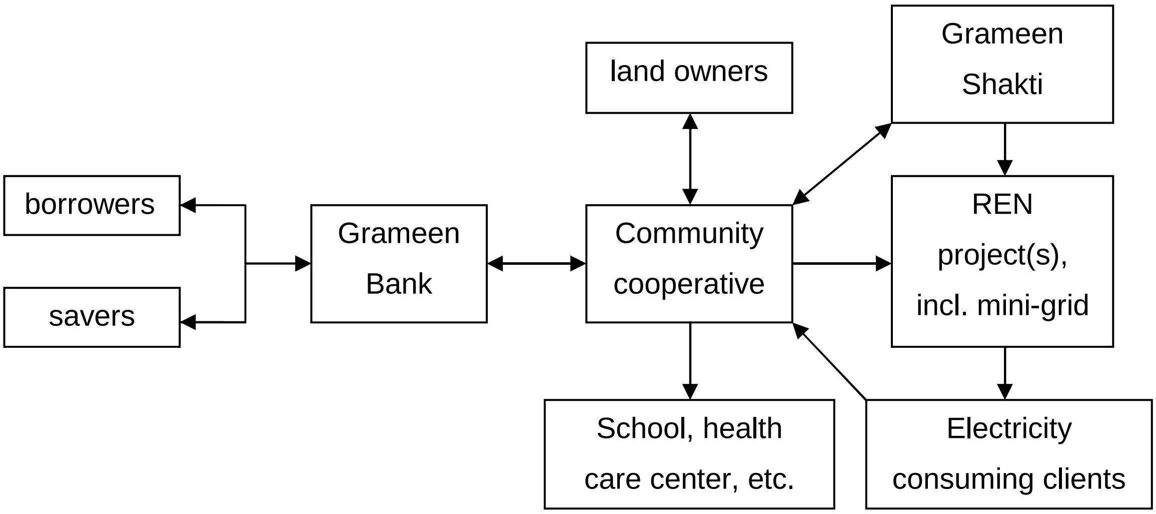

Figure 31: Possible structure of a community REN model (as social business)[168]

The following further stakeholders have to be considered in the community REN model, however are not shown in the figure above to ensure an optimized overview: public authorities, equipment supplying and construction company as well as insurance company;[169]

In order to start the business GS could provide seed capital (by means of buying the REN equipment and installing it). Money derived from co-op shares sold to rural households can then be used to gradually transfer the ownership of the REN installation from GS (eg 95%) to the co-op. If necessary, GS may also ask IDCOL for initial re-financing, which in turn can use funds of IFIs or, if possible, such funds may be directly channeled to GS. However, GS may be asked for adequate security and as given above the ultimate goal should be to attract rural shareholders and to become less dependent on subsidized loans. Details would have to be discussed. Also CDM credits may be used to initiate such projects. In the long run GS shall keep about eg 1% to 5% shares to preserve its interest in the co-op and to keep its involvement also as REN service provider (by operating and maintaining the REN installation). Due to the shares GS can also receive dividend after the business started to be profitable. However, GS' share in the co-op shall be kept small in order not to experience a conflict of interest as GS would be a service provider as well as a part-owner at the same time. As GS provides the seed capital as described above it is very probable that GS stays to be influential for the co-op anytime and hence

[168] author's own thoughts and suggestions including ideas of GS staff
[169] author's own thoughts and suggestions

can assure to keep the co-op on the right track. It is recommended to start such business models in small scale and to enlarge them as necessary (dependent on electricity demand and funds available). The 400 kW gasification plant described in the previous section has been chosen due to data availability to assess the economic feasibility of such plants. It is deemed that also smaller scale gasification plants are viable and for pilot-testing of the community REN model smaller installations may be targeted. As mentioned, also other types of REN technologies, eg PV or biogas, can be used for such purpose.[170]

As already described in the literature part various advantages, such as financial feasibility, social community benefits, creation of jobs, etc. can be achieved with a community REN model. In order to assess the rural household's view on such a model interviews have been undertaken in different villages in Sunamgonj area (Sylhet district) and in Shariatpur area (Dhaka district) as well as the staff of the related GS branch offices have been asked. The tenor for the model of the people interviewed was very positive. The following results have been derived:

Possible advantages:

- Many households interviewed said that a community REN model with a mini-grid may be a very good solution for remote areas, which are not connected to the public grid and where most households have not yet invested into a SHS.
- Even in case of availability of a public grid in a region, households often do not have electricity as they cannot afford the connection to the public grid and moreover approvals for grid connection often take a long time. Hence, an affordable community REN technology with a mini-grid may be a good option to offer alternative electricity access.
- Moreover, households connected to the main grid complain about frequent load shedding and some of them already invested into SHS in addition to the grid connection in order to overcome this problem. Hence, a reliable community REN model with mini-grid with constant power supply may be a favorable solution instead of the main grid.
- Some households said that in case electricity generated by a community REN model including a mini-grid would be cheaper than the electricity

[170] author's own thoughts and suggestions including ideas of GS and GB staff

supplied by the public grid (also considering connection costs) it would be very interesting to them.

- A low income household with an income of about 3,000 Tk per month informed that it cannot afford a SHS, but a mini-grid may be a great solution in case it could provide electricity for maximum 300 Tk a month. Another non-user informed that he could spend about 200 Tk per month for electricity supplied by a mini-grid.
- Another positive argument was that if there is a community REN installation with a mini-grid this may be more favorable than the main grid as during construction less trees may have to be chopped and the landscape may be less influenced at large.
- One person interviewed informed that he perceives larger installations with an attached grid to be more reliable, more useful and having a bigger impact than small scale home systems. In such case a community REN model may be favorable.
- Another person asked told that as people develop they also request more appliances which need more power respectively AC power and therefore grid based installations are deemed to be rather long lasting solutions compared to SHS. A community REN model can also be extended and hence provide more electricity when needed.
- In addition rural households said that if profits of a community REN model could be invested into common services, such as medical care centers or into infrastructure, such as roads, this would be perceived as being very advantageous for a community. Often health care centers are located far away (eg 60 km) and infrastructure is often very bad and especially during the rainy season travelling on mud roads is very challenging. Further, as education is highly valued investments into local schools would also be very much appreciated.
- Some of the men interviewed informed that their wives are already Grameen Bank customers and hence they know the company very well and already built up trust. They can also very well imagine that the community REN model can work.
- GS staff reported that in contrast to eg SHS, in case of a community REN model installation, operation and maintenance of a REN system can be eased due to a central location of the REN equipment.
- Another positive aspect under GS' view is that in case of a community REN model monthly installments do not have to be collected from households,

which is usually time-consuming and costly, but electricity fees are paid by electricity consumers. Further, in case of non-payment grid connections of related households can be cut off.

Possible hindrance:

- One household raised concerns that in some areas not enough households may be available to share a common REN installation and to set up a community REN model. Hence, an adequate population density is deemed to be necessary to successfully establish a community REN model.
- Another person interviewed said that in some communities households may just be too poor to have a community REN model established.
- Further, one household argued that in certain areas there is no unity between households in the vicinity and disputes occur frequently. A community REN model may only be successful in regions where strong ties between community members can be secured and households are not merely interested in their self-benefit.
- Some households said that they would not be interested in a community REN model as the main grid is already in their vicinity and they expect to be connected very soon (eg in about 1 to 2 months time).[171]

As could be shown in the previous section of this chapter a rice husk gasification project (as undertaken by IDCOL) can be financially feasible under consideration of certain aspects and could hence be used as REN installation for a community REN model. Dependent on each specific case of a community REN model adequate electricity fees have to be assessed. Fees shall be low to cater as many customers as possible. However, fees have to be high enough to compensate for all costs of the co-op (eg service fees of GS, rents, etc.) and to generate a certain profit to pay dividend to the shareholders and for being able to invest eg in community services, as suggested further above. As mentioned before, low income households informed they could spend maximum about 300 Tk per month as electricity fee. In order to get further ideas about the electricity fees chargeable the PV mini-grid pilot project of GS, which has been presented under section 3.2.11.6, can be reviewed as well as a PV mini-grid funded by IDCOL (more information on this project can be found in the excursus at the end of this chapter). Data for both mini-grids as well as for the rice

[171] Information provided by households and GS staff in Sunamgonj area (Sylhet division) in February 2013 and by households an GS staff in Shariatpur area (Dhaka division) in March 2013

husk gasification example discussed before is given in the following table. Further investigation into the community REN model as well as establishing related pilot projects may be undertaken in the future. The model may then be adjusted respectively extended as necessary according to practical experience.[172]

Table 20: Data of GS and IDCOL PV mini-grid and a community REN example[173]

	GS PV mini-grid	IDCOL PV mini-grid	Community REN model (rice husk gas. example)
Capacity	2.07 kWp (DC)	100 kWp (DC-AC)	400 kW (AC)
Project costs	608,400 Tk	53.21 mio Tk	91.94 mio Tk
End-users	20 households	390 shops, 5 health centers, 5 schools	75 kW silica production plant plus various private and commercial users
Tariff	approx. 51 Tk/kWh (calculated under the consideration of using a TV)*	32 Tk/kWh (fees related to diesel generator mini-grids in the area range from 52.60 Tk/kWh to 72.83 Tk/kWh; please note: related costs are high as the area concerned is a remote island)	7 Tk/kWh?**
Financing/ Ownership	The GS mini-grid has been financed by a grant given by Schneider Electric; GS owns 100% of the panels and grid line (land is rented by GS); battery, etc. are owned by the customers	20% equity of project company, 30% re-financed by IDA, 50% grant given by KfW	Seed capital from GS (respectively funding by IDCOL/World Bank, CDM), afterwards co-op shareholders
Status	Up to date 7 households are connected	successfully operating since 2010, no load shedding (larger battery bank and 40 kW diesel generator backup incl.)	Practical feasibility to be assessed

*) As given under section 3.2.11.6, in case of the mini-grid GS sells packages (including battery, charge controller, lights, etc.) and charges monthly electricity fees to its customers. In order to convert this into an electricity price per kWh the following consideration has been undertaken: GS informed that the related system costs for eg a TV connection (share of the package price related to the TV connection [due to use of the battery, charge controller, etc.]) amount to 3,000 Tk for

[172] Authors own thoughts
[173] Information provided by GS headquarters (Mr. Mollik Ali) on 7 March 2013 and 18 March 2013 and (Mr. Bikash) on 18 March and by IDCOL (Mr. MD Rahman) on 14 March 2013

five years (warranty period). Considering also a monthly fee of 60 Tk per TV (expecting 4 hours use per day) this would lead to an overall electricity bill of 50.93 Tk/kWh (120 hours use per month x 18 W (TV) = 2.16 kWh per month **->** 60 Tk monthly fee / 2.16 kWh per month = 27.78 Tk/kWh plus 3,000 Tk (TV share of cost) / 5 years (battery warranty) / 12 months / 2.16 kWh per month = 23.15 Tk/kWh). Dependent on the use of the battery customers may have to purchase a new one after 5 to 8 years. The cost of such a battery would amount to 6,757 Tk. Buying a new fan as included in the package would cost about 3,000 Tk. It has to be considered that in case of the GS mini-grid LED Schneider lamps are used which are rather expensive costing 2,000 Tk per piece in comparison to eg other LED lights which cost 500 Tk per unit. However, Schneider LED lights are very efficient, only consuming 2.5W. In case of use of AC lights in other mini-grids, such as CFL lamps (23W) or fluorescent lamps (40W), power consumption would be much higher. Thus, by considering the type of lamps used the GS mini-grid approach is efficient. GS used a pricing concept as given above, as electricity provided by PV mini-grid installations is not yet competitive with the main grid, which costs about 4 Tk/kWh to 7 Tk/kWh. However, in the future GS may consider charging fees per kWh consumed.[174]

**) 7 Tk/kWh have been assumed in the economic evaluation in the previous section of this chapter. Dependent on each specific project case (eg whether the main grid is also available in an area) the application of higher tariffs is also deemed to be feasible.

3.4.3.1 Excursus – IDCOL mini-grid

IDCOL established one 100 kW (220 Volt grid line; including DC-AC inverter) PV based mini-grid on Sandwip Island, Chittagong district, Bangladesh in 2010. The project can supply electricity to 390 shops, 5 health centers and 5 schools. Total project costs (including equipment, grid line, etc. and also a 40 kW backup diesel generator) amounted to 53.21 mio Tk. 20% of the total costs were equity contribution by PUROBI Green Energy Ltd (PGEL), 30% were re-financed by IDA and a 50% grant was given by KfW. The installation can generate about 137,500 kWh per year. Maximum demand is given between 6 pm and 10 pm. This project is successfully operating. Clients do not experience load shedding. To ensure uninterrupted supply a batter bank has been set up, which made of 30% of the total project costs and which led to a higher tariff. The tariff amounts to 32 Tk/kWh. A

[174] Information provided by GS headquarters (Mr. Mollik Ali) on 7 March 2013

tariff comparison has been undertaken in 2009 which showed that existing diesel generator operators demanded between 52.60 Tk/kWh and 72.83 Tk/kWh. Hence, a tariff of 32 Tk/kWh seemed to be adequate. IDCOL plans to finance 10 more mini-grids in the near future.[175]

3.4.4 Summary

After having been informed about GS' operations and Bangladesh's REN potential in previous chapters it became clear that GS has so far mainly been focused on SHS and also on biogas for electricity generation, but also rice husk gasification is a viable option. Hence, chapter 3.4 presented this technology also from an economic point of view by using the experience of IDCOL, which already installed two rice husk gasification plants in Bangladesh. It could be shown that under the given assumptions and pre-conditions (concerning project costs [investment costs and operating and maintenance costs], feedstock [rice husks], electricity produced and related sales price [fee], lifetime of the plant, equity and debt structure and sale of side products) such a plant can generate a positive net present value and hence be financially viable.

In order to provide funding for bigger sized REN projects (such as the rice husk gasification plant discussed or for installations like the GS PV pilot mini-grid) to serve many more clients and also to rely less on subsidized funds from IFIs a community REN business model has been presented in chapter 3.4. The related stakeholders (rural households as investors and also as electricity consumers, Grameen Bank, Grameen Shakti, land owners, etc.) and their interactions have been depicted and explained. Further, this chapter showed the findings of interviews undertaken with rural households in Sunamgonj area and Shariatpur area as well as with GS staff of related branch offices, who have been asked about their opinion on such a community REN model. Moreover, electricity fees charged (per kWh) by mini-grid owners have been compared by considering the experience of GS and IDCOL. Results derived may provide a basis for the calculation of proper fees for a mini-grid established under a pilot community REN model in the future. The next chapter will finally provide a conclusion on the paper and will present lessons learnt for other countries.

[175] Information provided by IDCOL (Mr. MD Rahman) on 14 March 2013

3.5 Conclusion, suggestions and lessons learnt

The paper has shown that by offering access to adequate financial services to the poor they can face improved living conditions and can lift themselves out of poverty. The theory part (2.1) as well as the empirical part (3.2) of the paper could confirm that provision of microfinance can entail very positive economic (eg income generation), human (eg education and health) and social (eg networking) impacts.

As chapter 2.1 showed, microfinance services can be feasibly deployed by following certain principles, such as joint liability, frequent repayment, proper interest rates, etc. By studying the famous MFI Grameen Bank (under 3.2.1) the successful application of such principles could also be confirmed by a practical example. The theory and empirical part of the paper introduced possible set-ups (eg as rural banks like Grameen Bank or NGOs) of MFIs and both parts confirmed that targeting women as MFI clients is very favorable as this effectively contributes to development. Chapter 2.1.10 provided lessons learnt of the MFI sector. The Grameen Bank experience showed that this MFI follows an exemplary approach, by staying in close contact with its customers, offering tailor-made financial solutions, focusing on productive use of loans, pursuing strict monitoring, etc.

The literature review in 2.2 and the practical example of Bangladesh (a country with high poverty rates) highlighted that developing countries often face a severe lack of energy supply which is hindering a country's development. In the introduction and under chapter 3.1 and 3.2 it could be shown that in case of Bangladesh only about 50% of the population has access to electricity and electricity has so far mainly been produced by use of gas, which is depletive. In case of the rural poor kerosene and diesel is usually used for lighting, etc. which is costly, entails adverse health effects and is not environmentally friendly. The paper (in theory and practice) showed that REN is very valuable as it leads to economic, health and environmental benefits (which will be more deeply discussed later on in the conclusions) and can supply adequate energy to the rural poor who are often without grid access. Hence, provision of reliable and affordable REN should be fostered. Due to lack of data, R&D and expertise REN has so far overall played a minor role in the country, although the REN potential is high in Bangladesh. Some efforts in promotion of REN have been set by the government recently, however it is advised to invest much more in this regard. Nevertheless, the private sector has shown some great achievements. As chapter 3.2 showed, the company Grameen Shakti, which is an affiliate of Grameen Bank, has successfully disseminated REN technology to the poor in rural Bangladesh since 1996. In chapter 2.1.11 it has been explained that by using REN for productive purposes, which is also promoted by GS, the vicious cycle of (energy) poverty can be broken. Theory (2.1.11) as well as practical examples (3.2) could show that by help of microfinance REN can be made affordable to the poor. Hence, microfinance has proven to be a meaningful tool to promote REN. 2.1.11 also introduced the UN CleanStart business model which could be applied for such purpose. In the empirical part (3.2) the approach of Grameen Shakti has been studied. Later on in the conclusions the CleanStart model and GS model will be compared.

As could be seen under 3.2, the vast network and also financial know-how developed by GB over the years has helped its affiliate GS to get introduced to its clients and to grow successfully. GS' main focus is to spread the use of reliable and affordable REN across Bangladesh by selling related equipment on credit. Chapter 3.2 showed that GS has been very successful in doing so. When comparing GB (as a MFI) and GS (as a REN technology supplier) it can be said that both companies in principle have the same target customers, namely the rural poor, however, in case of GB specific criteria for customer selection have been established and GB is merely focused on rural people whereas in case of GS basically anyone could be the customer as plenty REN customers shall be reached. Both companies intend to promote income generating activities. GB follows a rather self-reliant approach by having also savers and hence some incoming money whereas GS is presently dependent on funding by a financial institution called IDCOL, which in turn receives money from the World Bank, etc. It should be reviewed whether channeling funds from World Bank, etc. directly to GS would be possible respectively whether the discrepancy between the interest rates charged by IDCOL (eg 9%) and by IFIs (eg 2%) can be decreased in order to secure lower interest rates for GS and therewith also for its customers. Apart from that, solutions to overcome the dependency on incentivized loans and subsidies, which may not be available any time, shall be found. It is advised to follow a market-based approach in the future. As indicated under 3.2.12.1, GS shall try to decrease cost eg by making more use of local or own-manufactured equipment. Further, GS may extend its business operations and provide also other REN technologies respectively larger scale solutions and mini-grids. Such projects may also attract financially stronger customers and electricity generated can be made available to many rural poor. Moreover, GS may benefit from economies of scale. One idea to offer funding for such larger installations may be to apply “community REN models” (also stated under 2.2.2.8 and 3.4), which will be discussed in more detail later in this chapter. In such a case, rural households can take shares in a co-operative and can therewith become part-owner of larger REN installations. Further, by comparing GB and GS it can be said that GB uses peer groups to support high re-payment rates. In case of GS there are no peer groups set up, but ownership of REN equipment only passes over to the clients upon full payment and hence GS can take back systems in case of non-payment. Thus, re-payment rates in both cases are above 90%. GB requests weekly payment of installments and GS collects installments monthly. GS in contrast to GB applies flat interest rates (called service charge). In both companies no other fees are charged to the clients. Declined interest rates may be applied by GS in the future to lower costs for clients, which may also lead to earlier re-payment. However, as stated under 3.2.13 GS is facing high service costs and is also applying rather low interest rates. Therefore, flat rates can be justified. Both companies follow very close contact to its customers and both apply a strong audit and a good management information system by using self-developed computer software. GB is replicated abroad through the help of Grameen Trust. In case of GS no such special replication program has been set up yet, but it is strongly advised to consider this in the future as REN promotion shall also be fostered in rural areas of other developing countries and GS can provide valuable know-how and lessons learnt in this regard.

Chapter 2.2 showed that dependent on local specifics different REN technologies (such as photovoltaic, biogas, biomass gasification, wind power and micro-hydro) are available to provide energy to the poor. It has also been shown that REN equipment may have to be adapted to the requirements of developing countries. REN technologies for such purpose have to be rather simple and cost-effective. They can also be used complementary in hybrid solutions to secure on-going electricity supply or in mini-grids to cater more end-users. For proper handling of the respective equipment it is advisable to adequately train all local users. The empirical example of GS (3.2.11) specifically showed the experience with solar home systems and biogas in Bangladesh. Also improved cooking stoves have been presented, being one of the main products of GS. More detailed findings of the GS experience are provided further below.

After having reviewed existing literature as well as practical examples of microfinance in general and on opportunities of microfinance for REN promotion in developing countries in special it could be seen that microfinance can be used as an effective tool to provide poor people in developing countries with adequate financial means to afford REN technologies. To counter energy related supply problems of developing countries different types of REN solutions can be deployed, which can ideally be used for income generating activities. As a result poor people can escape the vicious cycle of (energy) poverty and hence sustainable development can be achieved. In the following, the research questions stated in the introduction of the paper shall explicitly be answered:

- **By taking the GS experience into account, A) which are the key success factors for sustainably promoting REN in rural areas of developing countries with help of microfinance and B) which advantages can be encountered by use of GS' REN technologies?**

Chapter 3.2 showed that the key factors for GS' success are to win trust, keep close contact to the customers and design products according to their needs. Clients shall be properly trained and rural communities shall be strongly involved also by employing them. Moreover, GS has been successful by engaging highly dedicated and competent staff, which is well trained. Further it provides qualitative products at best price, which can be achieved by undertaking on-going research and also by following own production, sourcing locally wherever feasible and by bargaining with suppliers. High up-front costs of the technologies can be encountered by offering innovative micro-loans to the customers. This as well as making use of the vast rural network, which has already been established by its affiliate Grameen Bank, helped to reach economies of scale. Another important aspect obeyed by GS is to offer reliable after sales service. Good reputation is very important as word-of-mouth has proven to be the most effective marketing tool. GS was very successful by starting off slowly and following steady improvement and innovation. To secure sustainable development GS also promotes productive use of REN which can lead to increased income of its clients.

Chapter 3.2.11.1 has shown that GS tries to encourage its clients also to apply the **micro-utility model**, by which owners of REN installations rent eg single lights to neighbors and hence the even very poor can be served. As the micro-utility model can increase income generation and also reach the bottom poor it is recommended to put much more effort to market this model. Some problems have been encountered with that concept, as people renting lamps overused the system and thus SHS owners stopped providing electricity. Such obstacles need to be overcome. Another option for income generation and also for reaching the very poor may be the “community REN model”, which will be discussed later in this chapter. The field review of the author has shown that the majority of GS' REN technologies installed are used by rural households rather than by shopkeepers. Hence, also in general GS shall lay more focus on the promotion of using REN for **increasing income** as this can lead to sustainable economic development, which has also been shown in the theory part under 2.1.11. However, dependent on the definition of productive use of energy, which has been indicated under 2.1.11, not only income generating activities themselves but also improved education and health due to access to electricity and lights, etc. can have a positive impact on a rural household’s economic situation. The real effect of GS' REN installations on income generation may be examined in a future detail study of present customers.

GS’ achievements as well as the financial sustainability of the business can also be attributed to the **strong** efforts of GS’ **audit department**, which have been discussed under section 3.2.9. The audit staff seems to be very effective to guarantee optimized business operations. GS’ strategy of dedicated and competent staff, high quality products and services, close contact to rural households, etc. also presented under 3.2.3 is strongly monitored by the auditors and headquarters and due to good performance GS could considerably increase its sales.

Further, the GS experience presented under section 3.2.11 has shown that **ongoing research and development** and related technological improvement shall be focused in order to offer the best technical solutions to customers. Eg GS now favors LED lamps due to better efficiency and fewer defects. Moreover, fiberglass biogas digesters, which can easily be installed, are leakage proof, etc., have been introduced and in case of the ICS improved stoves made of cement, brick chips and sand instead of mud have been provided since 2010.

When following GS’ business approach successfully, reliable and affordable REN can be widely promoted in rural areas and local communities can experience **significant advantages**. As section 3.2.11.2.2 clearly showed by use of SHS adequate lighting can be provided for education, working, etc. and kerosene and diesel can be saved which leads to economic (as fuel costs can be reduced and income increased), health, environmental (due to reduced emissions) and social (eg by community gathering) benefits. Also mobile chargers can be used, which leads to advantages in communication. Moreover, by access to SHS people do not counter problems of load shedding, which is often experienced by using the main grid. Also by application of the other REN technologies sold by GS, namely biogas and ICS, economic, environmental and health advantages can be achieved which has been presented under 3.2.11.3 and 3.2.11.4 respectively. Interviews showed that GS' customers are very satisfied with GS' REN technologies and services provided and in case of problems such are always solved by GS through immediate action. Only in some cases GS may provide more training to make the clients fully aware of the functioning of SHS and of proper handling in order not to overuse a system.

The paper showed that the benefits entailed with GS' operations lead to **advantages** on the **rural community level** but also on the **macroeconomic level**. In case of the former, next to the advantages such as health, etc. already mentioned, rural communities can make themselves also more independent by use of eg SHS as they can therewith get alternative energy supply to the main grid, which has been manifested under section 3.2.11.2.2. This leads to energy autonomy. Bangladesh as a whole can also become more independent from fossil fuel imports (indicated under section 3.1.3) in case of promoting REN technologies. Due to the use of GS' REN installations kerosene demand can be lowered and therewith also imports, which has been shown under section 3.2.12, which is also leading to an improved trade balance for Bangladesh. Thus, REN technologies can have a very far-reaching impact. Another example is eg, as shown under section 3.2.11.3, as the remaining slurry of the biogas production can be used to replace chemical fertilizers, which so far have largely been imported, Bangladesh can boost local production and therewith also local jobs and save on foreign reserves. In case of the organic fertilizer also extensive advantage can be gained from an agricultural point of view as such fertilizers can very well improve the soil leading to augmented harvests. This is very important for Bangladesh as the country is agriculture based. Moreover, eg section 3.2.11.2.4 showed that due to increased demand for equipment, such as batteries, local production in this sector rose, also leading to further jobs.

- **Which REN technologies could be applied in Bangladesh from a technical and (if technically feasible) also from an economic point of view and may be provided by GS in the future?**

In chapter 3.3 Bangladesh's REN sources have been reviewed. It has been derived that solar power can be largely exploited in Bangladesh due to favourable solar irradiation across the country. Also biogas production as well as biomass gasification (especially with rice husks) for electricity generation is a viable technology in the country due to abundant agricultural resources and feedstock available. Wind and micro-hydro power is another option in Bangladesh, however restricted to specific areas, most of them to be found in the South and South-East of the country, as adequate wind respectively hydrological conditions are only available in those regions. GS has already executed many solar and biogas projects and gathered extensive know-how in this field thereby. Rice husk gasification has so far not much been exploited in the country, but is deemed to be a viable option for large areas of Bangladesh and may be provided by GS in the future. Hence, a rice husk gasification project has been reviewed from an economic point of view under section 3.4. In the paper it could be seen that in case certain aspects, such as proper site selection to secure sufficient electricity demand and to guarantee adequate feedstock supply as well as also to consider the sale of side products, are observed rice husk gasification can be feasibly deployed.

- **Should community REN models based on microfinance be pursuit in order to spur economic and social development?**

The paper (chapter 3.2.11) has shown that so far GS mainly focused on small scale applications for rural households or small shops. However, it has also established one pilot PV mini-grid which could serve plenty of clients for which GS is looking for an investor. Further, it could be seen that due to financial constraints the very poor may not be able to afford a REN installation by their own but they may be able to rent lamps or pay small monthly fees for electricity provided by a mini-grid. In addition, the paper under 3.2.11 showed that electricity generation by use of biogas is rather feasible in case of mid to large size installations, which are usually not viable for single households due to lack of sufficient cattle, etc. respectively related feedstock. Also other technologies, such as rice husk gasification as just described above in the conclusions, can feasibly be deployed to generate electricity for a larger group of people, but funding has to be secured. Moreover, the paper under 3.2.11 and 3.2.12 showed that GS is relying on subsidized funds given by IDCOL and solutions for decreasing this dependency still have to be found. By application of a “community REN model”, which has been introduced in 3.4, all those challenges may be addressed.

As presented, the community REN model allows rural households (either by using micro-loans or savings) to become shareholders and hence part-owners of a larger REN installation by use of a co-operative, which can serve many customers with a mini-grid. Electricity customers pay a monthly fee to the co-op dependent on their consumption. Hence, by application of such a model also the collection of monthly installments as presently undertaken by GS staff becomes redundant, which is deemed to be favorable as this is very time consuming and hence also costly. Further, in case of non-payment of electricity fees the co-op can cut off the power line to the respective customer, which also brings some advantage in comparison to eg the present SHS scheme. In the community REN model shareholders can earn dividend. GB can handle financial transactions and GS can take care of the REN technology and can provide seed capital by installing a REN system and mini-grid in order to start off the business. If necessary, GS may derive necessary initial funds either via IDCOL or directly from World Bank, etc. or they may also make use of CDM credits. By selling shares to rural households the co-op can acquire capital, which can be used to gradually transfer the ownership of the REN installation from GS. Profits generated may not only be used to pay dividend but also to invest into community services, such as schools, and hence such a community REN model may also be considered to be a type of social business, which has been introduced in the paper under 3.2.5. Different types of REN technologies, also larger installations, can be used in such a model and can also complement each other in a hybrid system. As the REN technology can be centralized also installation, operation and maintenance is easier than in case of eg SHS. Further, the problem of load shedding, which is often encountered by use of the main grid, can be avoided by a mini-grid. Installing larger REN projects and using mini-grids for electricity distribution may also be favorable as high power consuming (AC) appliances (such as a fridge) can be used in such a case, which is impossible in case of using eg a SHS. As people develop an increase in demand for power intense devices is expected and hence mini-grids can be very advantageous also from a long-term perspective. In case of investing into larger installations also equipment cost may be relatively cheaper.

The above given shows that by use of a community REN model more clients can be reached, also the very poor. Different REN technologies can be used, not only those suitable for very small scale. Also power consuming devices can be used by rural households. Funds can be derived and rural households can become part-owners of larger REN installations. Jobs can be created. Income and profit can be generated for various stakeholders and the co-op's profit can be invested into community services. Interviews with various people showed a very positive tenor towards such a model. Some households reported that they already have experience with

Grameen Bank as well as with Grameen Shakti and they have built up trust. Hence, they believe such a model may work very well.

Research showed that the pre-conditions for such a model to work properly are to apply it in a densely populated area which lacks electricity and to choose an area where households have some income and where communities involved show strong ties. Adequate electricity fees shall be applied to cover costs, to generate some profit and to cater as many end-users as possible. Providing reliable and affordable electricity shall be the goal. By considering the above given, it is deemed that the community REN model is feasible and can bring plenty of benefits as described. It should be started on small scale and extended as necessary (dependent on demand and funds available). Hence, it is recommended to pursuit such a model to spur economic and social development. However, it may not work in each and every region respectively country due to cultural restrictions (lack of strong ties). A final discussion with GS management showed that other co-op trials have been undertaken in Bangladesh but with little success which was due to unfavorable cultural background. Further investigation into this model and pilot testing may be undertaken in the future to gather more insights.

- **Is the GS approach replicable in other countries?**

As shown under 3.2.14 the GS model is deemed to be replicable in other countries for individuals as well as for communities, where some income generation takes place. However, in each case local special characteristics have to be observed and the model may have to be adjusted accordingly. Suitable REN technologies have to be chosen dependent on local specifics. Adequate suppliers for qualitative cost-effective equipment, which may be more easily available with on-going research in the field, as well as committed and competent staff keeping close contact to clients have to be found. Cultural, legal, political and logistical aspects have to be observed. Availability of suitable microfinance schemes as well as sources for funding have to be secured. In each respective region REN demand has to be assessed as well as the economic growth potential. GS' replication shall be started first in a small-scale approach. When applied properly increased use of REN can bring considerable advantages leading to sustainable rural development.

As could be seen in the theory part of the paper (2.2.1) access to REN is tightly correlated with development. Hence, the application of REN technologies in developing countries shall be much more focused and using GS' experience therefore is deemed to be tremendously helpful. This may be undertaken by creating an “International Project Department” within GS, which offers training to interested foreigners and which also temporarily provides GS staff to successfully set up branch offices abroad. Proper funding often seems to be the bottleneck for project execution. Hence, awareness of GS’ operations and its replication potential shall be increased in the international community. Further, as many foreigners are visiting GS in order to learn about its operations a common online platform, which could be used to establish contacts between those visitors, may be helpful to allow for exchange of know-how and business ideas, etc.

Properly managed MFIs in developing countries may use the experience of GS and may finance REN technologies and co-operate with a REN technology supplier (option 1) and therewith contribute to REN promotion on large scale or separate companies like GS may be established as MFI affiliates, which can use the MFIs customer network and experience in microfinance products (option 2; like in the case of GB and GS). For such purpose it is advised to examine potential MFIs thoroughly. Literature review showed that some MFIs do not follow adequate business operations and are not properly catering the poor. Lessons learnt in the sector have been provided in 2.1.10 and should be applied when searching for a suitable MFI.

The CleanStart program established by the UN, which has been introduced in the theory part of the paper, under consideration of the extensive experience gained by GS could be used for promoting REN in developing countries as per option 1 explained above. As presented under section 2.1.11, in case of the CleanStart program well established MFIs can get pre-investment technical assistance, risk capital grants and concessional loans for being able to provide microcredit to end-users to finance clean energy. Technology suppliers respectively energy service providers are suggested to deliver REN technologies and services to end-user against cash payment. By comparing the CleanStart program and GS’ business it can be said that both approaches are very similar, except in case of GS the provision of micro-credit and sale and servicing of REN technology is basically combined under one roof. GS sells SHS, etc. on credit, provides services and REN users pay monthly installments (eg in case of SHS for three years). GS could profit from the experience of its affiliate MFI Grameen Bank to design proper payment schedules. GS also received grants and concessional loans to start and grow its business. The CleanStart program suggests MFIs to assess their client’s current energy costs and willingness and ability to pay for clean energy, which is also performed by GS. Both approaches also consider carbon credits to be a potential source of funding (please see 3.2.12.2 in this regard). Thus, well established MFIs can apply the lessons learnt provided by GS and can use them in other developing countries to promote REN. For doing so, it may be favorable to follow option 2 as just described as in case of separating microfinance and REN equipment supply institutionally companies engaged may face difficulties. Eg customers may not re-pay a loan to a MFI in case problems arise with the REN equipment involved, for which a REN equipment supplier is responsible. Having multiple companies involved may lead to a conflict of interest and hence it is advised to keep financing and supply of REN equipment under one roof (like in the case of GS). Further relevant insights may be derived by pilot replication projects in the future.

Acknowledgements

First and foremost I would like to express my sincere gratitude to Grameen Shakti and Grameen Bank staff and clients, who largely contributed to the thesis by providing relevant information during numerous discussions and who offered many constructive comments. Therewith, I would especially like to thank Mr. Fazley Rabbi (GS) and Mr. Morshed Golam (GB) for continuous support and best co-ordination. Further, I would like to thank Mr. MD Rahman, (IDCOL), for providing precious information on rice husk gasification and on mini-grids. I am also much obliged to the many people in Bangladesh who made my stay a very pleasant one despite of severe political unrest in the country at that time.

Moreover, I would like to acknowledge my thesis advisor Mr. Roggenbauer (Technical University Vienna, Energy Park Bruck/Leitha) who, thanks to his immense knowledge in the REN sector, could provide great support and also to Mr. Monga (UNIDO) who offered helpful comments on the paper.

Last but not least I would like to thank my family and friends, also from the MSc course, as well as my employer Voith Hydro for their great company, motivation and valuable support.

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Interviews:

Grameen Bank
2013-02-17: International Program Department:
Mr. Ratan K. Nag (Deputy General Manager, Chief), Mr. Golam Morshed Mohammed (Senior Principal Officer), Mr. Harun-Or-Rashid (Senior Officer)

2013-02-19 and 2013-02-20: GB Branch Office (0333-587) in Vouel, Mirzapur, Gazipur district: Mr. Belayet Hussain (Branch Office Manager)

Grameen Trust
2013-02-25: Mr. Chowdhury (Assistant General Manager)

Grameen Shakti
at GS headquarters
2013-02-25, 2013-03-05 and 2013-03-06: Mr. MS Islam (GS Head of Department of International Cooperation & Development)
2013-02-25, 2013-03-05 and 2013-03-06: Mr. MA Gofran (GS Biogas consultant)

2013-2-25: Ms. Kader (GS intern)
2013-03-03: Mrs. Amin (founder and president of GSBP)
2013-03-04: Mrs. Wimmer (GS author)
2013-03-03, 2013-03-04, 2013-03-05: Mr. Haque (GS Deputy General Manager)
2013-03-04 and 2013-03-06: Mr. Rabbi (GS Senior Manager)
2013-03-06: GS Audit Department
2013-03-05 and 2013-03-07: Mr. Amin (GS Zonal Manager)
2013-03-06: Mr. Reza (GS Assistant General Manager, head of IT)
2013-03-07 and 2013-03-18: Mr. Ali (GS Deputy Manager)
2013-03-18: Mr. Bikash (Head of Finance & Accounts)

field trips
2013-02-26 until 2013-02-28: GS Branch Office in **Sunamgonj**, Sylhet division: Mr. MD Shahidul Islam (Branch Office Manager) and his staff (interviews have been taken with 13 households in the villages of Jogairgaon, Lalarchar, Khairghat, Bate Sadekpur) and related GTC staff

2013-03-09 until 2013-03-13: three different Branch Offices in **Shariatpur**, Dhaka division: Mr. DM Jalal (Divisional Manager) and Mr. MD Kamruzzaman (Regional Manager) and their staff (interviews have been taken with 29 households from the following branch offices: Shariatpur, Moderhat and Chikondi)

Documents received from GS
Power Point Presentation:
Kamal, A. (2012): “A Sustainable Social Business for Renewable Energy & Environment in Bangladesh”

Leaflets:
GS SHS leaflet (March 2013), GS Biogas Program leaflet (March 2013), GS ICS leaflet (March 2013)

Infrastructure Development Company Ltd. (IDCOL)
2013-03-14: Mr. MD Rahman (Senior Technical Investment Officer)

Annexes

Annex 1: Interview – guideline: GS client's REN questionnaire

Date: …………………….

Place: ……………………

Name:

No. of family members:

Average monthly income:

1.) Are you an owner of a REN technology?
   - In case of yes, please mention which one and specify details (capacity, payment schedule, etc.): ………………………..
   - In case of yes, do you sell electricity/gas or rent lamps to your neighbors?
   - In case of use as a shopkeeper: Could you increase your income by use of the REN system?
   - Have you experienced any problem with your REN system?
   - In case of no, do you know about REN technologies?
2.) What do you think are the advantages of using a REN system (eg instead of using kerosene lamps, etc.)? (Health, environmental, social, economic benefits?) How did you learn about the REN system? Do you recommend the system to others?
3.) Would you in principal invest into a community REN model (first model to be explained)? Would you use your savings to invest into a community REN project to receive a dividend? Do you think your community members would invest into such a model?
4.) What do you think may be the advantages/disadvantages of a community REN model? (eg REN becomes more affordable, jobs can be created, technical know-how can be transferred, community services [eg schools] can be funded, etc.)

Annex 2: Rice Husks Gasification (400 kW; economic appraisal)

Year	Discounted CF (Tk)	Nominal CF (Tk)	O&M (Tk)	Investment (Tk) and spare parts	Rice husks (Tk)	Electricity sale (Tk)	Silica sale (Tk)	Discounted Costs (Tk)
			8%		5%	5%	5% escal.	
0	-91.940.000	-91.940.000		-91.940.000				91.940.000
1	9.248.847	9.711.290	-3.277.508	-679.500	-3.024.000	7.056.000	9.636.298	6.648.579
2	30.296.312	33.401.684	-3.539.709	-1.019.250	-3.175.200	7.408.800	33.727.043	7.015.110
3	42.191.684	48.842.148	-3.822.886	-1.359.000	-3.333.960	7.779.240	49.578.754	7.356.308
4	54.389.803	66.111.145	-4.128.717	-1.359.000	-3.500.658	8.168.202	66.931.318	7.394.758
5	54.345.995	69.360.791	-4.459.014	-1.359.000	-3.675.691	8.576.612	70.277.884	7.438.566
6	54.296.878	72.763.010	-4.815.735	-1.359.000	-3.859.475	9.005.443	73.791.778	7.487.682
7	54.242.496	76.324.639	-5.200.994	-1.359.000	-4.052.449	9.455.715	77.481.367	7.542.065
8	54.182.880	80.052.790	-5.617.073	-1.359.000	-4.255.072	9.928.501	81.355.435	7.601.681
9	54.118.056	83.954.868	-6.066.439	-1.359.000	-4.467.825	10.424.926	85.423.207	7.666.504
10	54.048.044	88.038.568	-6.551.754	-1.359.000	-4.691.217	10.946.172	89.694.367	7.736.517
11	53.972.852	92.311.894	-7.075.895	-1.359.000	-4.925.777	11.493.480	94.179.085	7.811.708
12	53.892.486	96.783.162	-7.641.966	-1.359.000	-5.172.066	12.068.155	98.888.040	7.892.075
13	53.806.940	101.461.011	-8.253.324	-1.359.000	-5.430.670	12.671.562	103.832.442	7.977.620
14	53.716.205	106.354.411	-8.913.590	-1.359.000	-5.702.203	13.305.140	109.024.064	8.068.356
15	53.620.262	111.472.674	-9.626.677	-1.359.000	-5.987.313	13.970.397	114.475.267	8.164.298

NPV	638.429.740	
Ann.	61.507.782	(average constant yearly returns)

NPV of costs	205.741.830
Annuity of costs	19.821.639

Investm.horizon	15	yr
WACC/risk adj.disc.rate	5%	
Rated capacity	400	kWel
Plant operation	3.000	h/yr
Investm. costs (no subsidies) (Tk)	91.940.000	
O&M costs (Tk)	3.034.730	/yr
O&M cost escalation	8%	
Fuel costs (rice husks) (Tk)	2.880.000	/yr
Fuel price escalation	5%	
Electricity wholesale price (Tk)	7	/kWh
Electricity price escalation	5%	
specific investm.costs (Tk)	229.850	/kW
specific fuel costs (Tk)	3.000	/MWh
specific O&M costs (Tk)	3.161	/MWh
yearly electricity generation	960	MWh
Capital Recovery Factor	0,096342288	

Please note:
A load factor of 80% is assumed.
The silica sales figures have been provided by IDCOL.
1 EUR = 103 Tk (March 2013)