

Final Report [NOT APPROVED]

On

“Feasibility Study for Selecting the Most Promising and Feasible Renewable Energy Based Solution(s) for Blue Gold Program”

Submitted to,



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Abdullah Al Shakib

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Disclaimer

These are the views and expressions of the author of this report, and do not necessarily represent the view of the Netherlands Embassy in Dhaka, the Republic Government of Bangladesh or Blue Gold program consultants.

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Acronyms

AC	Alternate current
Ah	Ampere Hour
ADB	Asian Development Bank
BCCRF	Bangladesh Climate Change Resilience Funds
BDT	Bangladeshi Taka
BG	Blue Gold
BPDB	Bangladesh Power Development Board
BRAC	Bangladesh Rehabilitation Assistance Committee
BREB	Bangladesh Rural Electrification Board
BWDB	Bangladesh Water Development Board
CFL	Compressed Florescent Lamps
CPL	Consiglieri Private Limited
CSPS	Containerized Solar Power System
DAE	Department of Agricultural Extension
DC	Direct current
DEP	Diesel Exhaust Particles
DFID	Department for International Development (UK)
DSM	Demand Side Management
EPC	Engineering, Procurement and Construction
GIZ	Deutsche Gesellschaft für Internationale
GoB	Government of Bangladesh
GPD	Gallons per Day
GPM	Gallons per Minute
GPOBA	Global Partnership for Output Based Aid
GS	Grameen Shakti
HDPE	High Density Polyethylene
HH	Household

ICS	Improved Cooking Stoves
IDCOL	Infrastructure Development Company Limited
IETC-UNEP Program	International Environmental Technology Centre of the United Nations Environment
IPSWAM	Integrated Planning for Sustainable Water Management
IRPS	Improved Rice Parboiling System
IRR	Internal Rate of Return
JICA	Japan International Cooperation Agency
Kw	Kilo Watt
Kwp	Kilo Watt Peak
LED	Light Emitting Diod
LSP	Local Service Provider
M&O	MILENA-OLGA
MW	Mega Watt
NGO	Non-Government Organization
NPV	Net Present Value
PCM	Phase Change Material
PGEL	Purobi Green Energy Limited
PO	Partner Organization
PSCU	Power Supply Control Unit
PV	Photovoltaic
REB	Rural Electrification Board
RET	Renewable Energy Technology
RREL	Rahimafrooz Renewable Energy Ltd.
RSF	Rural Services Foundation
SAT	Sustainability Assessment of Technologies
SG	Smart Grid: Power Matcher
SHS	Solar Home System
SIP	Solar Irrigation Pump

SMG	Solar Mini Grids
SNG	Solar Nano Grid
SPDW	Solar Pump for Drinking Water
SWOT	Strength Weakness Opportunity Threat
THM	Trihalomethane
UK	United Kingdom
UNDP	United Nations Development Program
UNEP	United Nations Environmental Programme
USAID	United States Agency for International Development
USD	US Dollar
W	Watt
Wp	Watt peak

Executive Summery

Blue Gold Program (a collaboration between the Netherlands and Government of Bangladesh), since its inception in 2013, has been one of the prime development interventions protecting the inhabitants of the south western polder areas of Bangladesh aiming- to reduce poverty of one hundred and fifty thousand households living in selected coastal polders by creating healthy living environment and sustainable socio-economic development. Consiglieri Private Limited (CPL) was assigned by Blue Gold to conduct this assessment where CPL would first shortlist the most suitable and potential renewable energy based technologies, and then would analyze feasibility of those technologies and select the most feasible and promising technologies for Blue Gold areas.

In this assessment, the study team has adopted customized Sustainability Assessment of Technologies (SAT) method in assessing feasibility of RE based technologies. The study has three major analytical phases: Technology Screening (Literature Review, Technology Screening According to Different Criteria, Shortlisting Technology), Technology Feasibility Analysis (Technical Feasibility Analysis, Social Feasibility Analysis, Environmental Feasibility Analysis and Financial Feasibility Analysis) and Analyzing Market and Business Possibilities (Target market for the technologies, Usage of the technologies and Business Model Attributes and Requirements of the technologies)

At this very first stage, a list of technologies was generated from literature review and key-informant interviews. We reviewed existing documents, journals, articles and project reports for identifying renowned and promising renewable energy based solutions (biomass, solar thermal, solar photovoltaic, hybrid, etc. based) in this country and worldwide.

With this list of technologies, CPL went through the SAT prescribed screening phase. Four broad categories were used in this phase for screening the renewable energy based solutions. These were (1) Technical, (2) Social, (3) Environmental, and (4) Financial criteria.

At the end of the screening phase, CPL has developed a list of four potential technologies for further assessments. These four technologies are: SHS (Solar Home System), SNG (Solar Nano Grid), SIP (Solar Irrigation Plant) and Containerized Solar Power System (CSPS).

After technology screening, the researchers of CPL went to the field (polder areas and other areas where different RE technologies are being used), collected data on those technologies. The researchers then talked to users and non-users, NGOs, private market actors, public bodies, enterprises and other stakeholders and collected detail data regarding these technologies. CPL also collected data against different technical, social, environmental and financial criteria. List of actors interviewed has been shared in Annex.

After all the data are collected, CPL researchers analyzed the feasibilities of the shortlisted technologies against different SAT criteria and scored each technology. They have tried to determine against which feasibility criteria a particular technology performance is strong or weak. We assigned 'low/ medium/ high' scores against different sub-criteria on a basis of a scale of 1-3. Different weights were assigned against different criteria. Weights were put per client priority and renewable energy expert suggestions.

Through this feasibility analysis CPL has found out SHS to be acceptable in all four criteria. SHS currently is the most widely used renewable energy technology, used not only within the polder region but all around the country. As this technology is already widespread and a popular rural name, taking this

technology to household level in polder area would be comparatively easier and less costly. The technology thus is very much feasible on technical and financial feasibility analysis. The technology utilizes really small amount of space and it is environmentally friendly giving it a good analysis on environmental feasibility analysis as well.

SNG has greater technical, social, financial and environmental feasibility and can be used in wider variety of rural applications. Capable businessmen, entrepreneurs and SMEs can set up an SNG system and can sell electrification service to clusters comprising households, farmers, shops and SMEs at markets. The system on rural areas can also be diverted towards electrification of irrigation pump thus serving another important purpose. The demand for this system yet may not be high but its service potential and demand will grow if more awareness of its benefits can be created within polder regions.

SIP is a low-cost solution and has already been tested and piloted in different parts of the country. So it can be a reliable irrigation alternative for polder farmers as it will help to reduce costs and lower diesel dependency. It has good energy efficiency and management is simple. However, SIP will require fresh water source for pumping..

CPL researchers through this study found CSPS as a quiet promising technology. A CSPS system can be used for electrification a community alongside support irrigation or local shops and businesses. Schools and local clinics can also benefit from this multipurpose technology. However, the study has found that CSPS system is unfeasible in terms of financial criteria. This situation is due to its high purchase cost. As there are no present use of this technology in Bangladesh the technology poses severe supply and maintenance difficulty. Getting local spare parts that are compatible with this technology is another challenge. The study team however finds that this technology is highly promising if implemented properly. With collaboration with REB there is a huge prospect of piloting this technology within polder region. At remote location where electrification is not possible or very distant this technology can be proper solution.

Based on our data collected from different users, non-users and market actors (including private, public and development actors involved in the sales and promotion of RE technologies), at this very last stage we assessed business and market possibilities of the feasible RE technologies. For this we considered the following factors: Target Market, User and Usage and Business Model Attributes and Requirements.

At this stage we conducted our analysis on Solar Home Systems, Solar Nano Grid and on Solar Irrigation pump. We excluded Containerized Solar Power System because through our second stage we found it not to be financially feasible.

Almost all the rural households in the polder regions can be users of SHS technology (even on-grid households as there are concerns about the quality of electrification). Rationale behind this is that SHS is a small portable system that can be easily set up and does not require much space or high level of maintenance. It requires very small amount of investment and now also available as relief good by KaBiKha and TR in polder areas. The target market can also be classified into two broader categories.

Households within the REB electrification grid primarily use SHS electrification as backup for load shedding. They are also a reliable source of power during natural disaster. And the usage of solar power reduces cost. Households outside the reach of REB grid coverage use SHS power as their sole electrification source. Here basic need of light and charging of a mobile phone are generally met by SHS.

Many shops, Farms, workshops, fishing ghers with REB electrification use SHS electrification as a backup during load shedding. Outside REB electrification use SHS electrification as a primary source of power.

SNG has similar target market like SHS. But with increased output and broader application range, rural SMEs and households that demand enhanced energy output might also be potential target market for SNG. However, the target market need to be closely clustered households and business centers (rural market places, shops and workshops).

Close-knit households within and outside the REB electrification grid primarily can use SNG electrification as backup for load shedding or as primary electrification source. This is also a reliable source of power during natural disaster. The SNG electrification can also play a major role in cost reduction for on grid users. Close-knit shops and workshops of village market with or without REB electrification can use SNG electrification as their primary or secondary source of electrification.

In polder areas farmers and local service providers (who will sell irrigation services to community farmers) would be the target market for SIP. Currently most of the irrigation in that region are done by diesel powered pumps. Diesel is an expensive fuel and farmers often must wait in queue for a long time as number of service provider is not sufficient against number of service receivers. Therefore, SIP can be an attractive alternative for both farmers and local service providers.

After the completion of our study we found that Solar Nano Grid (SNG) as the most feasible technology among others. This is because of the following attributes: Multiple applications and usage, Business Feasibility and Marketability.

Both for on grid and off grid support SNG holds many positive attributes. Therefore SNG projects by Blue Gold would be highly beneficial for the people of polder region. To accommodate SNG projects within polder region CPL has identified some recommendations for Blue Gold. CPL has recommends Blue Gold to develop an understanding and cooperation with REB to identify partnership possibilities and gain greater knowledge about the electrification prospects of the region. Therefore Blue Gold can identify territories where electrification would be very late or by renewable energy solutions. SNG projects within those areas would have good success probability. Furthers recommends to develop partnership with potential development partner organizations. This would allow Blue Gold the added resource and support of those organization on various aspects of the project. Furthermore CPL recommends Blue Gold to create partnership opportunities within the polder region with local actors. This would be a vital step to maintain local participation and interest thus increasing success probability.

It also being recommended to pilot PCM equipped Dutch technology of standalone blast freeze system based on CSPS and test its business possibilities. By introducing new technologies and business modalities Blue Gold can fill necessary needs and improve living standard.

Chapter One: Background and Introduction

1.1 Background

Bangladesh, the biggest delta of the world (known as The Ganges–Brahmaputra Delta or The Green Delta), has total 5107 km of coastal line embankment in 123 Polders¹, where 49 polders are sea facing. Since 2000, the Bangladesh and the Netherlands Government are cooperating closely together in the coastal zone of Bangladesh to create an environment conducive for sustainable economic growth with close involvement of the local communities. About 38% of the population in the coastal regions of Bangladesh live below the poverty line and face high vulnerabilities in terms of insecurity of food, income, water and health.

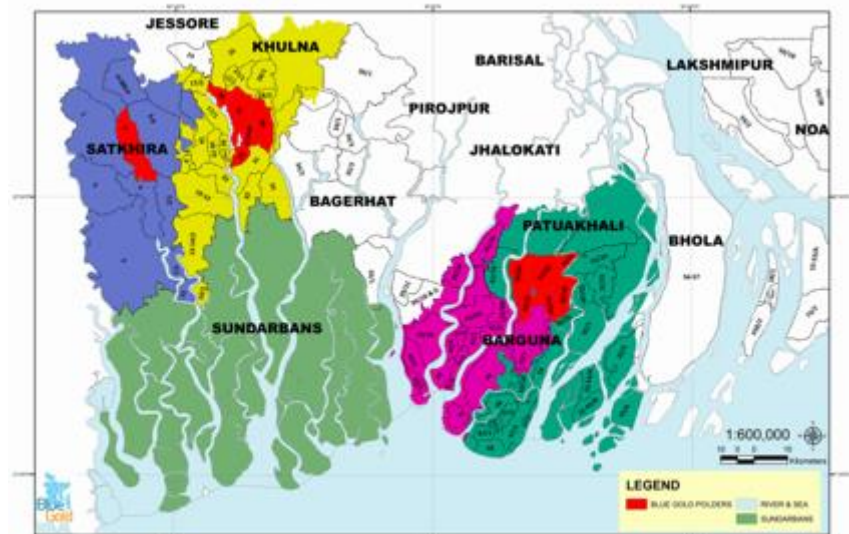


Figure 1.1.1: Blue Gold Polder map

In this situation, Blue Gold Program, started on 2013, has been a collaboration initiative between the Government of the Netherlands (donor) and the Government of Bangladesh. The program is implemented by the Ministry of Water Resources, through Bangladesh Water Development Board (BWDB, lead agency) and the Department of Agricultural Extension (DAE). The Program establishes and empowers community organizations to sustainably manage their water resources, and based on their priorities, delivers the services for which those community organizations have expressed a demand. Blue Gold builds on the results and lessons learned from previous programs and projects in Bangladesh, notably the Integrated Planning for Sustainable Water Management (IPSWAM) program (2003-2012), Southwest Area Project, Char Development & Settlement Project-IV etc. and the Bangladesh and Dutch experiences and expertise in participatory water management in polders. The Blue Gold Program has been one of the prime partners for protecting the inhabitants of the polder areas aiming: *To reduce poverty for 150,000 households living in 160,000 ha area of selected coastal polders by creating a healthy living environment and a sustainable socio-economic development.*

And in order to ensure the sustainable socio-economic development, energy is at the heart of widespread social, economic, and climate problems. But a significant portion of the Blue Gold program area do not have access to electricity. Some of these areas only have access to Palli-Bidyut (electricity from BREB-

¹ A polder is a low-lying tract of land enclosed by dikes that forms an artificial hydrological entity, meaning it has no connection with outside water other than through manually operated devices.

Bangladesh Rural Electrification Board), but services are quite unstable and comparatively expensive. This has been significantly affecting the livelihood of poor people, potential for enterprise development and economic growth in the program areas.

In these circumstances, Blue Gold Program was interested to deploy some smart and efficient renewable energy solutions to mitigate the energy demands in the polder areas. But because at present there are no popular, cost-efficient and marketable renewable energy solutions in the market, Blue Gold intends to conduct a proper feasibility analysis to substantiate the most promising and feasible renewable energy solutions based on economic viability, operational considerations, inclusive applications and value chain integration.

On this backdrop, Consiglieri Private Limited (CPL) was assigned to conduct this assessment where CPL would first shortlist the most suitable and potential renewable energy based technologies, and then would test feasibility of those technologies and select the most feasible and promising technologies for Blue Gold areas.

1.2 Study Objectives

In order to identify the most promising and feasible renewable energy based solution(s), the study is proposed to be divided in two phases or milestones:

- A. Shortlisting the most suitable and potential renewable energy based technologies
- B. Detail Assessment of the most promising and feasible renewable energy based solution(s) considering technology, demand, and supply along with energy situation within the polder regions.

1.3 Methodology

1.3.1 Technical Approach

In this assessment, the study team has adopted customized Sustainability Assessment of Technologies (SAT) method in assessing feasibility of RE based technologies. International Environmental Technology Centre of the United Nations Environment Program (IETC-UNEP) developed this technology assessment methodology known as Sustainability Assessment of Technologies (SAT) in late 90s. The SAT integrates environmental, social and economic considerations; and thus focuses on environment and development together and puts them at the center of the economic and political decision making. In SAT the technologies with potential undergo multi-tiered progressive assessment (screening, scoping and detailed assessment). SAT has received international praise and approval and different renowned agencies have been using it for technology assessment. Along with original SAT method, CPL has added analysis of Market and Business Possibilities of different technologies so that Blue Gold Program can intervene with potential technologies in polder areas.

The following figure shows the major analytical steps that we followed in this study. As we can see, the study has three major analytical steps:

1. *Technology Screening*

- a. Technology Shortlisting
 - i. Literature review (including REB policy review)
 - ii. Key Stakeholder Interview
- b. Technology screening according to different criteria
 - i. Screening by Technical criteria
 - ii. Screening by Social criteria
 - iii. Screening by Environmental and Policy criteria
 - iv. Screening by Financial criteria
- c. Shortlisting technologies for feasibility analysis

2. *Technology Feasibility analysis*

- a. Technical feasibility analysis
- b. Social feasibility analysis
- c. Environmental feasibility analysis
- d. Financial feasibility analysis

3. *Analyzing Market and Business Possibilities*

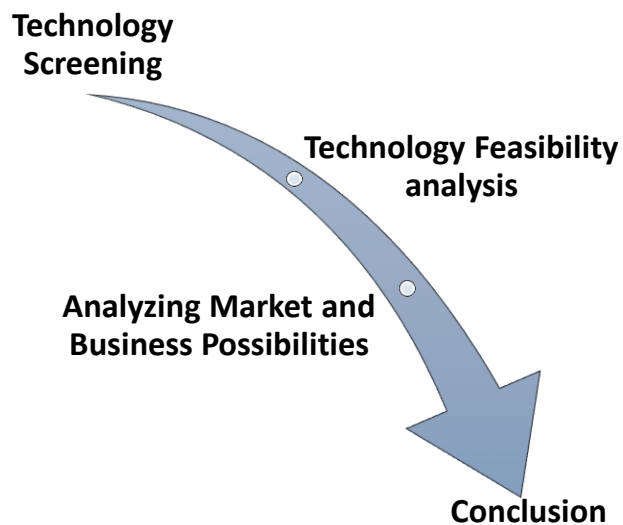


Figure 1.3.1: Analytical steps

1.3.1.1 Methods Adopted of Technology Screening

At this very first stage, a list of technologies was generated from literature review and key-informant interviews. We reviewed existing documents, journals, articles and project reports for identifying renowned and promising renewable energy based solutions (biomass, solar thermal, solar photovoltaic, hybrid, etc. based) in this country and worldwide. Literature on relevant Dutch solutions was also be reviewed. We reviewed project reports by BPDB (Bangladesh Power Development Board), GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit), REB (Rural Electrification Board of Bangladesh), RET (Renewable Energy Technology), IDCOL, Grameen Shakti, Rahimafrooz, UNEP, UNDP, ADB, World Bank, etc. Besides, GoB policy recommendations, subsidy options and government's energy distribution policies were also reviewed in order to identify policy focus in the southern Bangladesh in the coming years/ decades.



Figure 1.3.1.1: Steps in Technology Screening

After literature review, relevant persons from this network were identified and the study team sat with key private sector actors, research entities and development partners that had been working in renewable energy sector and/or have relevant knowledge and experience on renewable energy solutions.

After that with talked to regional REB officials and collected their electrification plan of polder areas in next five years. We identified whether RE technologies really have any potential or future in polder areas.

List of actors CPL researchers has interviewed is shared in Annex C.

After these steps the team came up with a list of promising renewable energy based solutions that have been successful in national or foreign set-ups or have interesting or promising features and potentials for scale up.

With this list of technologies, CPL went through the SAT prescribed screening phase. Four broad categories were used in this phase for screening the renewable energy based solutions. These were (1) Technical, (2) Social, (3) Environmental, and (4) Financial criteria.

The sub criteria were chosen especially keeping in mind the demand scenario in the Blue Gold program area, i.e. energy demand of the poor living in the southern delta area of Bangladesh.

At the end of this phase, CPL team has selected some potential technologies (screened) for further feasibility analysis in the next phase.

1.3.1.2 Methods Adopted in Feasibility Analysis

After getting a short list of RE technologies from technology screening, we went to the field (polder areas and other areas where different RE technologies are being used), collected data on those technologies. We talked to users and non-users, NGOs, private market actors, public bodies, enterprises and other stakeholders to collect detail data regarding these technologies. CPL has also collected data against different technical, social, environmental and financial criteria. List of actors interviewed by CPL is shared in Annex.

After all the data are collected, we analyzed the shortlisted technologies against different SAT criteria and scored each technology. CPL team tried to determine against which feasibility criteria a particular technology performance is strong or weak. The assigned 'low/ medium/ high' scores against different sub-criteria on a basis of a scale of 1-3.

Different weights were assigned against different criteria. Weights were put according to client priority and renewable energy expert suggestions.



Low



Medium



High

Under technical criteria, CPL research team has assessed each technology against factors like compatibility of the technology with local and natural conditions, performance, extent of local material usage, availability of local expertise, output of energy, ease of maintenance and durability of components.

Under social criteria, CPL research team has assessed each technology against factors like potentiality for job creation, acceptability in local culture, income generation potential, potential for improving quality of life, occupational safety and health conditions and gender sensitivity.

In case of assessing environmental feasibility, criteria CPL research team has considered to include risk for communities, raw material consumptions, risk for the environment and biodiversity, impact on common goods, extent of use of renewable energy, environmental resilience and emissions.

While assessing financial feasibility, CPL research team has considered mostly the financial viability of the technology. Keeping in consider the capital investment and operating cost. We also conducted cost benefit analysis alongside operating and maintenance cost.

At the end of this phase CPL research team has evaluated which technology is technically, socially, financially and environmentally feasible or not.

1.3.1.2 Method of Assessing Market and Business Possibilities

Based on our data collected from different users, non-users and market actors (including private, public and development actors involved in the sales and promotion of RE technologies), at this very last stage CPL has assessed business and market possibilities of the feasible RE technologies. For this consideration of the following factors were made:

- Target Market: Through our discussions with experts and field visits we identified the most probable market for each of the technologies
- User and Usage: Through our discussions with experts and other market actors we identified the most probable users and usage rational for each of the technologies
- Business Model Attributes and Requirements: We identified effective business models and their operational requirements for each of the technologies.

1.3.2 Sampling Plan

In sample selection, data collection and analysis CPL research team has used Grounded Theory Approach and analysis. In this approach, respondents were selected and interviewed until repeated answers were found. As researchers collected and reviewed the data, repeated ideas, concepts or elements became apparent, and were tagged with codes. As more data were collected, and as data were re-reviewed, codes were grouped into concepts, and then into categories. These categories became the basis for new theories or facts.

Data from different stakeholders in the market system under different technologies (including technology users and non-users, SMEs, technology traders, development actors and public bodies that have been involved with sales, promotion, testing, piloting or usage of different RE technologies) has been collected by CPL research team.

The table below shows types and number of actors we interviewed with.

Type of Actors	Number of Interviews	Area
Government (REB)	11	Dhaka, Satkhira, Patuakhali and Khulna
RE tech. Users	23	Satkhira, Khulna, Jessore, Kushtia, Bagerhat
Donor Agencies	7	Dhaka
NGOs	9	Dhaka, Satkhira and Khulna
RE Technology sellers/ Private market actors	6	Dhaka, Satkhira and Khulna
Experts/ Academicians	6	Dhaka, Satkhira
BG Project staffs	3	Satkhira, Khulna, Patuakhali

1.3.3 Study Limitations

1. In the initial phase of this study, we had to rely on the experts and officials of renewable energy sector. It was difficult for us to reach to them and get sufficient data from them. This significantly disrupted our planned timeline.
2. For the data on international technologies, we had to rely on skype calls or email conversations with innovators and service providers spread around the world. It was often difficult to get response from them using these media. Unfortunately, data shared by them for detail assessment phase was not enough and we could not analyze those technologies as detail as required.
3. This was not a purely scientific study. For data against different indicators like CO₂ emission, hazards, economic and social benefits, we had to rely on the data supplied to us by users and/or sectoral experts. We did not have the to test/ verify those data in a scientific way.
4. Except Solar Home System (SHS), most RE technologies were piloted or tested by different development projects. Hence, we did not find long-term users or established market actors for most of the assessed technologies. Therefore, for data on technology desirability, feasibility or viability of different solutions, we had to depend on expert or user interviews or documentations shared with us by service providers.

Chapter Two: Policy Framework Related to Electrification of Polder Regions

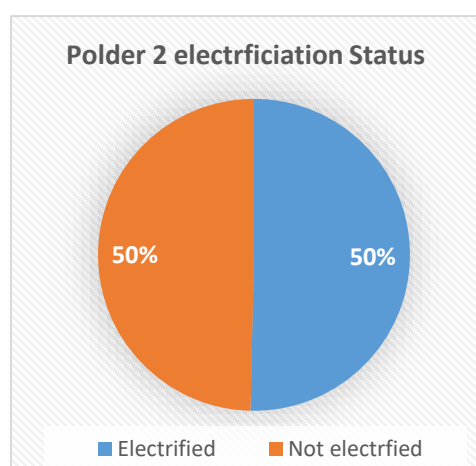
It was important for CPL to know about existing electrification situation and government's plan for electrification in polder areas in the next few years. The reasoning behind this action is that this would guide CPL researchers for analyzing specific user need and identify right RE technologies.

So CPL research team has sat with Rural Electrification Board or REB which is Bangladesh government's institution in charge of rural electrification development all over Bangladesh. With the help of their data researchers were able to determine the current situation of electrification and future goals according to their policy within the polder regions.

Following tables and diagrams represent existing electrification status and projected electrification plan by REB in different polder areas.

2.1 REB Electification Status: Satkhira

Polder Name	Upzilla	Union Under this Polder	Connected Household	Number of Household	Percentage of Electrification	Total electrification of Polder	Plan about 100% Electrification
2	Asasoni	Budhata, Kulla	27,729	62,285	44.51%	50%	December 2018
	Satkhira Sadar	Brahma Rajpur, Fingri, Dhuliha, Labsa	60,658	82,209	73.78%		



Polder 2

Area: Within Asasoni Upazilla with part of Satkhira Sadar.

Current status: 50% electrified.

Complete electrification by: December 2018.

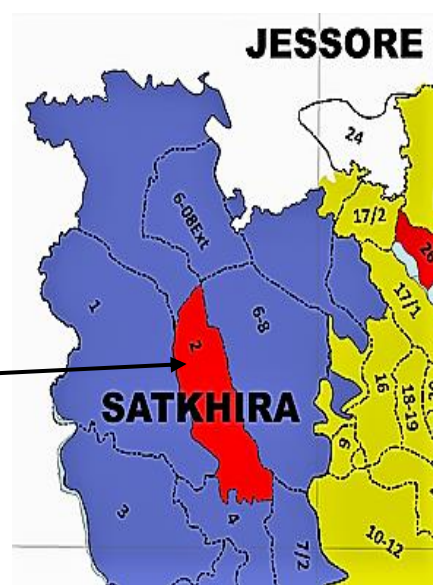


Figure 2.1: Satkhira electrification Situation

2.2 REB Electrification Status: Khulna

Polder Name	Upzilla	Union Under this Polder	Percentage of Electrification	Plan about 100% Electrification
22	Paikgacha	Deluti	40%	December 2018
26	Dumuria	Sobhna	84%	September 2017
29	Dumuria	Dumuria, Shahas, Bhandarpara	78%	June 2018
	Batiaghata	Surkhail		
30	Batiaghata	Gangarampur, Surkhail	64%	June 2018
31	Batiaghata	Surkhail	64%	June 2018

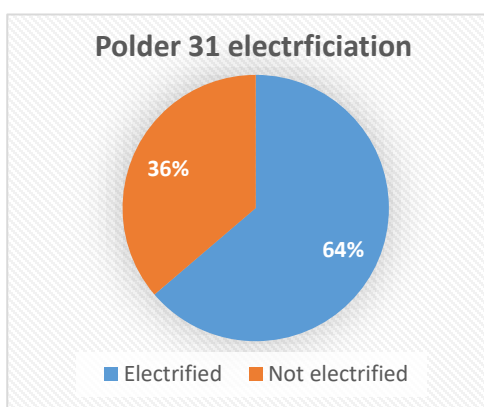
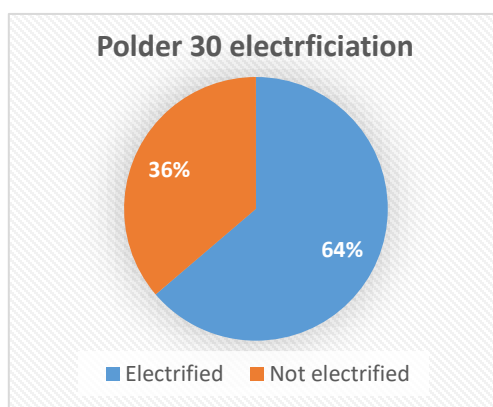
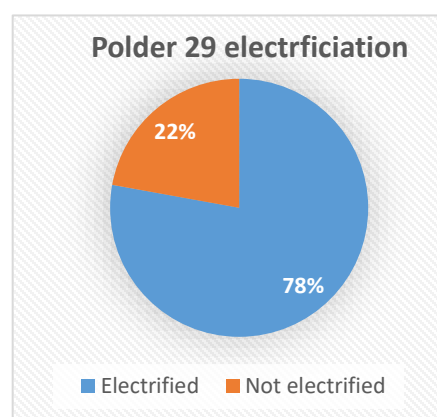
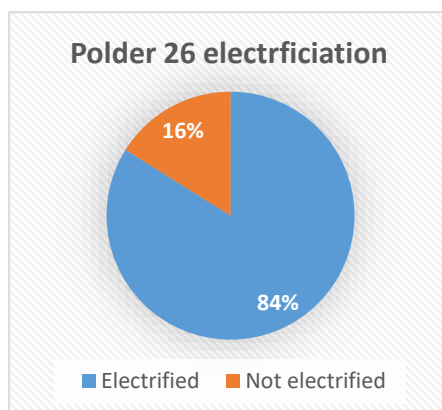
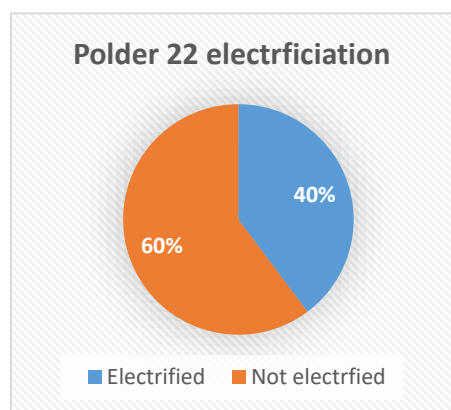
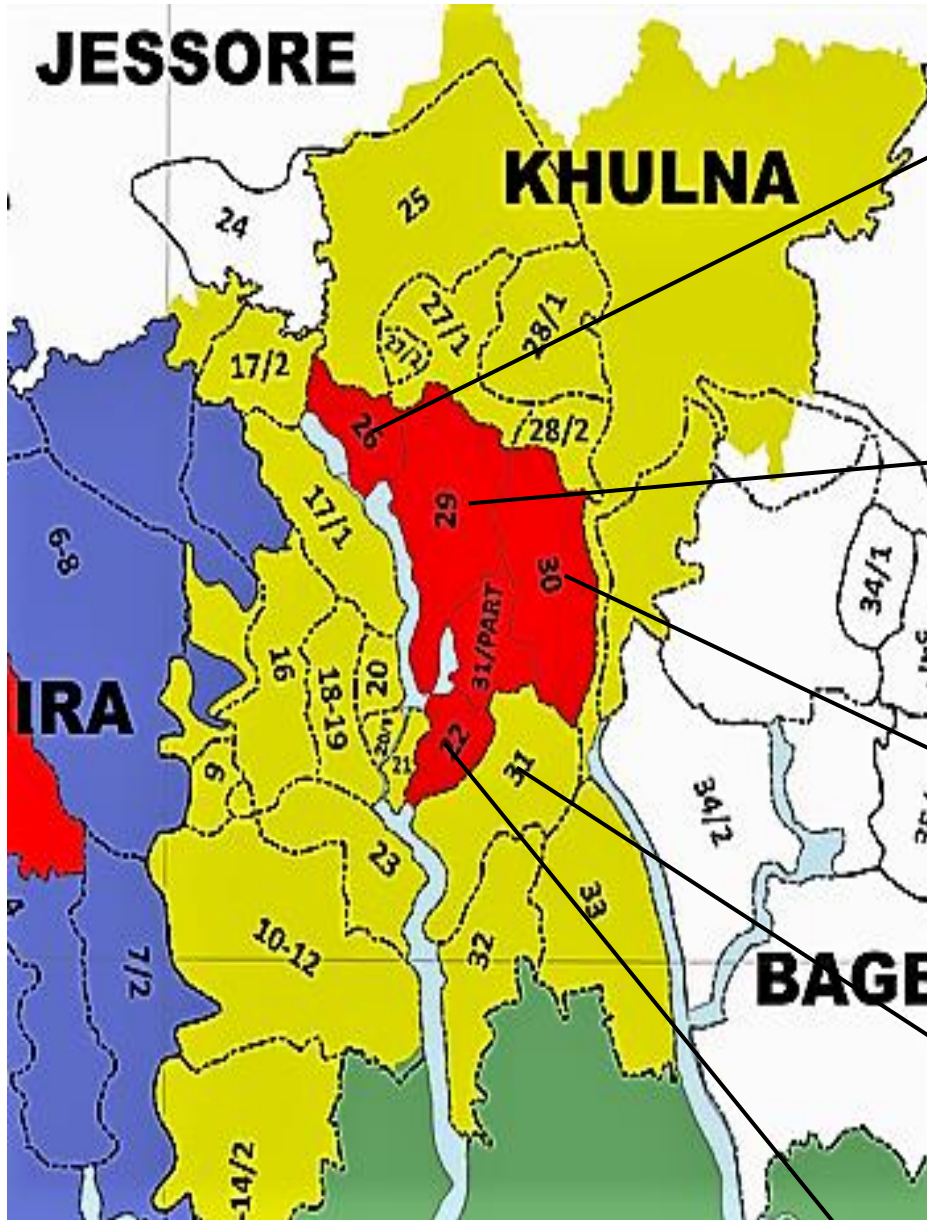


Figure 2.2: Khulna electrification Situation

Khulna Working Area- Blue Gold



Polder 26

Area: Within Dumuria Upzilla

Current status: 84% electrified.

Complete electrification by:
September 2017.

Polder 29

Area: Within Dumuria and Batiaghata Upzilla

Current status: 78% electrified.

Complete electrification by: June 2018.

Polder 30

Area: Within Batiaghata Upzilla

Current status: 64% electrified.

Complete electrification by: June 2018.

Polder 31

Area: Within Batiaghata Upzilla

Current status: 64% electrified.

Complete electrification by: June 2018.

Polder 22

Area: Within Paikgacha Upzilla

Current status: 40% electrified.

Complete electrification by:
December 2018.

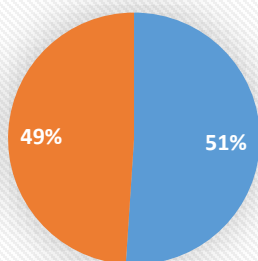
2.3 REB Electrification Status: Patuakhali

Note: Through interview with REB officials we only received Upzilla electrification situation.

Table 2.3: Patuakhali electrification Situation

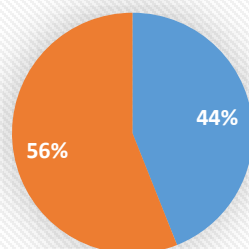
Polder Name	Upzilla	Union Under this Polder	Percentage of Electrification	Plan about 100% Electrification
43/2A	Patuakhali Sadar Upzilla	Choto Bighai, Bara Bighai, and Madarbunia unions	51.052%	2018
	Amtoli Upzilla	Gulisakhali		
43/2E	Patuakhali Sadar Upzilla	Jainkati	43.96%	2018
43/2D	Patuakhali Sadar Upzilla	Patuakhali Sadar	43.96%	2018
43/2B	Patuakhali Sadar Upzilla	Auliapur	40.012%	2018
	Golachipa Upzilla	Amkhola		
43/1A	Amtoli Upzilla	Atharagashi and Kukua	22.28%	2018
43/2F	Amtoli Upzilla	Gulishakhali	22.28%	2018

Polder 43/2A electrification



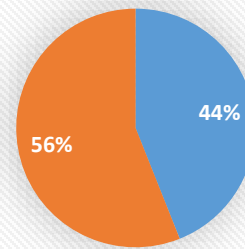
■ Electrified ■ Not electrified

Polder 43/2E electrification



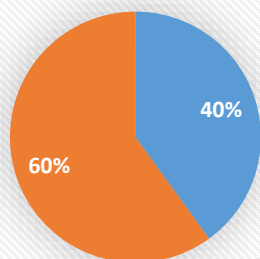
■ Electrified ■ Not electrified

Polder 43/2D electrification



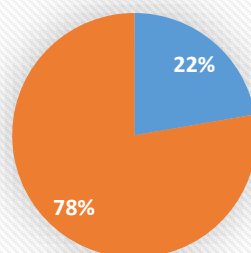
■ Electrified ■ Not electrified

Polder 43/2B electrification



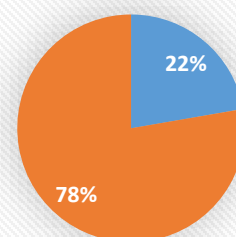
■ Electrified ■ Not electrified

Polder 43/1A electrification



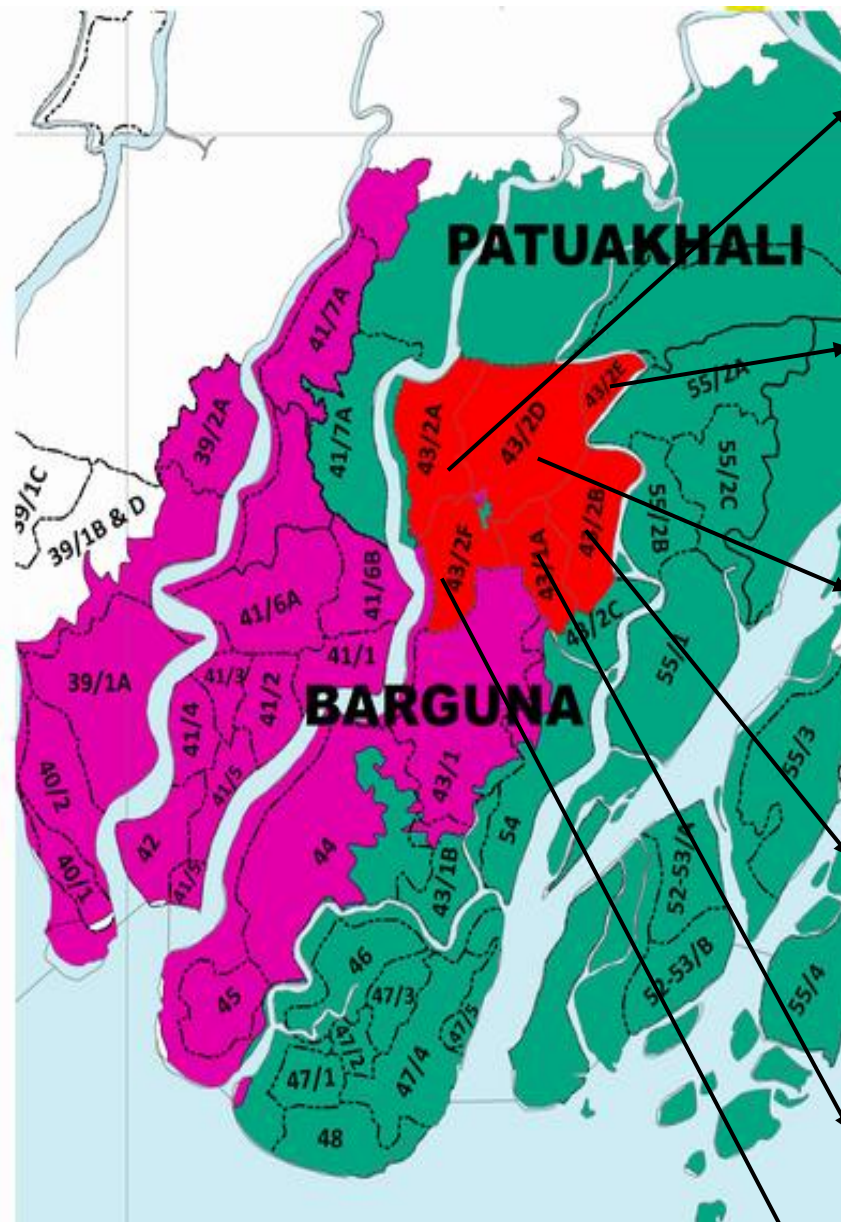
■ Electrified ■ Not electrified

Polder 43/2F electrification



■ Electrified ■ Not electrified

Patuakhali Working Area: Blue Gold



Polder 43/2A

Area: Within Patuakhali Sadr and Amtoli Upzilla

Current status: 51% electrified.

Complete electrification by: December 2018.

Polder 43/2E

Area: Within Patuakhali Sadr Upzilla

Current status: 56% electrified

Complete electrification by: December 2018.

Polder 43/2D

Area: Within Patuakhali Sadr Upzilla

Current status: 56% electrified.

Complete electrification by: December 2018.

Polder 43/2B

Area: Within Patuakhali Sadr and Golachipa Upzilla

Current status: 40% electrified.

Complete electrification by: December 2018.

Polder 43/1A

Area: Within Amtoli Upzilla

Current status: 22% electrified.

Complete electrification by: December 2018.

Polder 43/2F

Area: Within Amtoli Upzilla

Current status: 22% electrified.

Complete electrification by: December 2018.

2.4 Strong potential of Expanding Market of RE Technologies in the Polder Region

If the existing electrification situation is analyzed in the polders areas, from the above figures and boxes it can be seen that in Satkhira (polder 2) 50% households are still not connected to grid. In Patuakhali this percentage varies from 50% to even 80% across different polders. And in Khulna this percentage of non-electrification is also very high. However, from discussions with REB officials CPL research team has found that REB has a general plan of 100% electrification of entire country by 2021. But this generic plan does not indicate the portion in which REB intends to provide electrification through renewable energy.

Thus, this can be understood that there is still room for renewable energy projects within the polder region. However, price effectiveness of development projects might play a big role in ensuring sustainability of those projects. Expensive projects in locations which would be under electrification within a short period will not be a successful investment.

Along with this issue, quality of electricity was identified as another important factor that has been playing a major role in increasing the use of RE technologies in polder areas (and all over Bangladesh). Issues like long load shedding hours and long distance between electricity supply port and application point have been recurring concerns even in the communities connected to main grid. Thus, many households have been using RE technologies as a backup source even in the communities that are connected to the grid (we will discuss more about this issue in following sections).

Therefore, there is still strong potential of expanding market of renewable energy technologies in the polder region in coming years. But before any relevant intervention, whether grid connection will interfere or affect RE system must be assessed. A case is presented below where unplanned RE establishment became unsuccessful was deserted.

CASE STUDY: How REB Interventions Can Affect RE Initiatives

Around the end of 2012, the Rural Electrification Board of Bangladesh started a project of renewable energy support for Dhulihar village at Satkhira. The project implementation support was provided by RahimAfrooz. The project was a dual purpose project with a goal to support irrigation alongside electrification of the area. Mr. Abdur Razzak is a local resident of Dhulihar village. He became a part of this project and offered his 12 decimal land for the purpose.



Figure: Deserted RE Electrification System

He was highly motivated for this project as this would provide his land irrigation and fish farming opportunity, alongside additional income. With 24 batteries and 56 solar panels the project was very promising. The total capability of solar panels were 6.72 Kwp. Among this 3.36 Kwp for water pump. And the other 3.36 Kwp for electrification. Using the electrification section, 15 households were provided electrification from 5:00pm to 11:00 pm. For this service REB used to charge 105tk from each household. This was running properly for 2 years and Mr. Abdur Razzak was enjoying additional income from this. However, electrification project began to fail by December 2014 as REB began to connect the locality with main power grid. Community people began to move away from solar electrification in favor of the grid support.

Chapter Three: Technology Screening

In this phase, through literature review, REB policy review and interviewing key market stakeholders we developed a list of potential RE technologies. Then CPL research team screened those technologies through SAT prescribed four broader criteria (technical, social, environmental and financial). At the end of this phase, CPL team came out with a list of four potential RE technologies of which feasibility analysis was conducted (Chapter Four).

3.1 Technology Shortlisting using Literature Review and Key-Informant Interview

A detailed literature review is provided in the Annex. Some important findings are summarized below:

- Bangladesh is situated between 20.30-20.38 degrees north latitude and 88.04-92.44 degrees east which is an ideal area for solar energy. Taking an average solar radiation of 1900 KWh per square meter, total annual solar radiation in Bangladesh is equivalent to 1010×10^{18} J. Present total yearly consumption of energy is about 700×10^{18} J. It shows that even if 0.07% of the incident radiation can be utilized, total requirement of our energy can be met. At present energy utilization in Bangladesh is about 0.15 Watt/Square meter land area, whereas the availability is above 208 Watt/Square meter. This shows the enormity of the potentiality of renewable energy based technologies.
- Surveyed Blue Gold program areas are partially connected to the grid. On an average half of the households in these areas have been found to be connected to the grid. However, significant portion of the grid customers have been found to be not satisfied with the services. For example, 40 percent of the customers in Budhata union have been found to be not satisfied with the service of Palli Bidyut Samiti (PBS) the grid connected electricity provider in the area.
- In general households having access to electricity enjoy benefits such as reduced fuel cost, extended working hours, increased income, increased reading habits, and above all an improved living standard.
- Different field assessments have revealed load shedding to be the lead cause for dissatisfaction among the customers. On an average, every customer household goes through 2 to 7 hours of load shedding per day. Rechargeable lights and kerosene lamps are the main source of light during power cuts.
- Difficulties in getting connections has been identified to be a major obstacle on the way of rural electrification. Survey results show that many households and businesses get their connections (illegal ones) from other households or businesses as getting legal connection from PBS appear to be too complex a process to them.
- In both the surveyed areas, households not connected to the grid have been found to be mainly relying on kerosene lamp (Kupi) and lantern (hurricane); and over 50 percent of the households have been found have Solar Home Systems (SHSs). However, over half of the households having SHSs have systems with capacity 40 watt or below which fulfill minimum lighting requirements.
- While the Blue Gold program area population is predominantly dependent on agriculture for their income; significant portion of these households have enterprise engagements (naturally these are SMEs). Lack of access to electricity or non-satisfactory service from PBS is perceived by the

people to be preventing local entrepreneurs from gaining as per their potential. For example, cattle rearing households are unable install electric fan which could save their cows from excessive heat, food shop owners are suffering due to not having refrigerators, mill operators having to rely on high cost fuel operated generators etc. On an average, 70 percent non-electrified shops and business owners perceive loss (not getting optimal benefits) from their enterprises due to not having electricity.

- While in alignment with government plans, REB is aiming to cover 12 to 83 percent of non-electrified households in Blue Gold program area by 2020; LNG and coal based power plants to be established near these areas may take as long as 10 years. Thus at this moment the only way left to cover the non-electrified household by 2020 is through additional electricity supply from the national grid, which may be quite difficult (considering ever increasing electricity demand in the country).
- Average electricity demand in the non-electrified households in the program area is from 45.4 KWh to 65.4 KWh. The uses of this electricity vary from lighting to irrigation and standalone SHSs do not have the capacity to provide such amount of electricity. On the other hand, Solar Mini Grids (SMGs) can provide an optimal solution to the problem. A grid system can provide sufficient electricity to meet such demand as it has some advantages over the standalone systems (SHS, solar lanterns etc.).

From literature review and key informant interview we found that wind and hydro based RE technologies are extremely expensive and are not suitable or affordable by the rural households in polder areas. These technologies require huge funds and support from the government or development programs. Therefore, we excluded Hydro and wind based technologies from further consideration. Then we came up with a list of potential RE technologies that have been piloted, promoted, tested or marketed in our country or abroad.

SMG (Solar Mini Grids)	SPDW (Solar Pump for Drinking Water)
SIP (Solar Irrigation Plants)	IRPS (Improved Rice Parboiling System)
Biogas Plant	Municipal Waste
ICS (Improved Cooking Stoves)	Organic Photovoltaic
Biomass Gasification	Smart Grid Solution
Solar Roof Top	Thin-film Based Technology
Solar Parks	Containerized Solar Power System (CSPS)
Solar Water Heating	SPDW (Solar Pump for Drinking Water)

3.2 Technology Screening using Screening Criteria

After we generated a list of potential RE technologies (the sixteen technologies tabulated in the above section), we put those in a matrix with the pre-set selection criteria (customized from SAT's general framework) and screened through yes/no type binary checkbox exercise. Four broad categories were used in this phase for screening the renewable energy based solutions. Those were (1) Technical, (2) Social, (3) Environmental, and (4) Financial screening criteria. Under these four broader criteria groups, we used nine sub-criteria for technology screening. The criteria set in screening phase were set specially based on perceived field level realities (grasped through review of literature) as well as based on expert opinion.

The Screening Matrix is given below. As we can see in table, any option that did not qualify under one or more mandated conditions was automatically screened out from consideration.

Table 3.1: Screening matrix for primarily selected technologies

[illegible]

As it can be seen in the matrix (Table 3.1), at the end of the screening phase, CPL team got a list of four potential technologies for further assessments. These four technologies are:

- SHS (Solar Home System)
- SNG (Solar Nano Grid)
- SIP (Solar Irrigation Plant)
- Containerized Solar Power System (CSPS)

Because one of the key program level objectives of Blue Gold is to increase rural household level income through electrification, CPL research team has mostly concentrated on the technologies that generate electricity for livelihood, business or agricultural purpose for the polder inhabitants.

Technologies like biogas plant, solar roof top and solar park got screened out because installing these technologies involve significant space and cost requirements which is not suitable for polder area or its inhabitants. Improved cook stove was not accepted for further assessment because it is injurious to environment. Biomass Gasification, IRPS, SPDW and Smart grid solutions were not accepted because of their poor business prospects (reflected in different previous project documents).

In the next chapter, CPL research team has discussed about the findings of the feasibility analysis of the shortlisted four RE technologies.

Chapter Four: Feasibility Analysis

After completion of screening four technologies have been selected by CPL research team. In this section, an understanding has been created on different aspects of feasibility of these technologies within the context of polder region alongside a good understanding of market and business possibilities of these technologies.

In the sections below, for each technology first CPL team has provided a brief background which comprises historical context of that technology. Then discussion about demand-supply situation of that technology in the market (user profile; users' feedback; different types of market actors; their business performance; challenges, etc.) has been provided by CPL team. Then CPL research team has analyzed technical, social, financial and environmental aspects of these technologies and tried to determine along which feasibility criteria a particular technology performs well or poorly. CPL did this analysis against different SAT criteria and scored accordingly.

Lastly, discussion about market and business possibilities of that technologies considering polder context is provided by CPL research team.

4.1. Solar Home System (SHS)

4.1.1 Background

Solar home systems (SHS) are stand-alone photovoltaic systems that offer a not so cost-effective mode of supplying amenity power for lighting and appliances to remote off-grid households. In rural areas that are not connected to the grid SHS can be used to meet a household's energy demand fulfilling basic electric needs. Globally SHS provide power to hundreds of thousands of households in remote locations where electrification by the grid is not feasible. Solar Home System constitutes of a package of Solar panel, battery and accessories, providing light and a way of living in those areas not connected to the grid. Though SHS is not very cost effective comparing with other alternative options, considering the fundamental need, value of public benefits of renewables and broader opportunity cost it is still an economically viable option.

SHSs can be used to light up homes, shops, fishing boats etc. It can also be used to charge cellular phones, run televisions, radios and cassette players. SHSs became popular among users because they present an attractive alternative to conventional electricity such as no monthly bills, no fuel cost, very little repair, maintenance costs, easy to install anywhere and most importantly the credit facility of payment etc.

Most of the distribution of SHS was done by POs (Partnering Organizations) of IDCOL under micro-credit scheme and with subsidy. After 2013 the installation of SHS has been declined due to decrease of subsidy. At present subsidy is offered (by IDCOL) only for the 30Wp and below 30Wp systems. Field study found another interesting fact that numbers of non-branded retailers are selling SHS in a significantly low priced packages and the sales has not declined anyway. Good portion of the sales of these systems being in informal market the exact data is not available.

SHS have been successfully distributed around the world, Bangladesh has installed over 4,000,000 systems to date. The figure below describe illustrates year-wise installation of SHSs in Bangladesh up to 2015. And economically, a population of 160 million offers enormous demand for solar modules because of their

price point, efficiency, and ability to alleviate, even if marginally, the broader problem of electricity in the LDC.

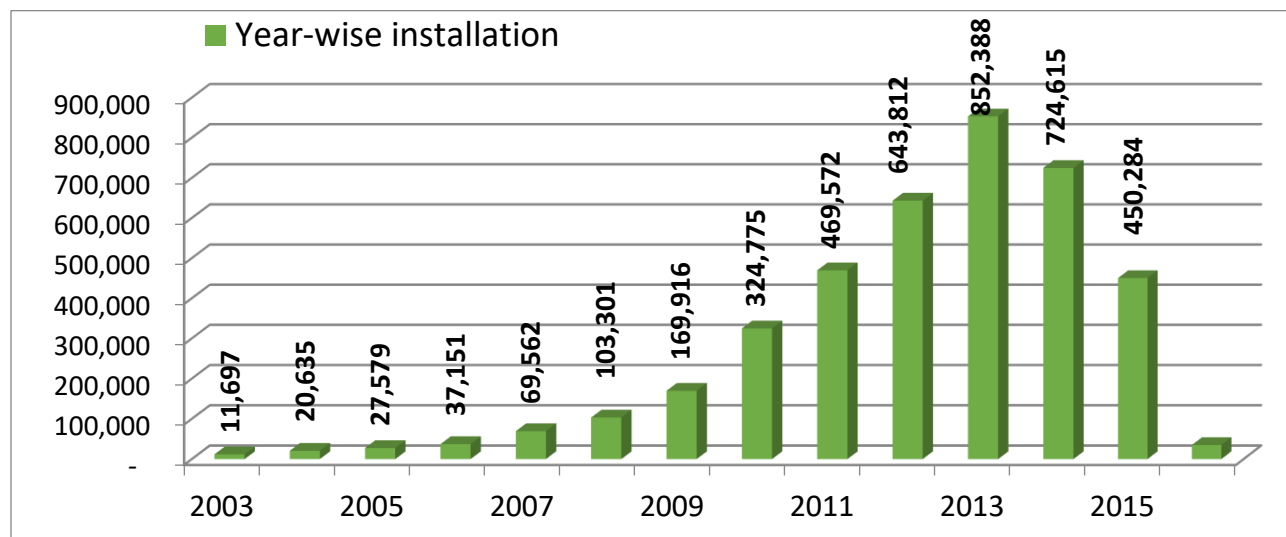


Figure 4.1.1: Cumulative no of Solar Home System module installation in different year

One demerit of this technology is that any excess power generated due to bright sunshine or long hours of sunlight cannot be utilized and is therefore wasted. However, recently, after the worldwide success of the SHS in off-grid, isolated regions, new concepts and basic design systems are emerging to scale up the SHS, maintaining their low cost while at the same time addressing some of their limitations.

4.1.2 Demand and Supply Situation of SHS

The demand of SHS is ever increasing as more and more people wish to find an alternate source of electrification. A reason for the increase of SHS demand would be that the capability and willingness of customers have increased. People within the polder region no longer find the one shot payment a big discomfort due to their current economic condition. And the general willingness to be under complete or partial electrification 24 hours a day makes the growing appetite for SHS technology product sustainable.

Another reason behind the increase of demand can be contributed to the simplicity of the technology in use. SHS is small, cheap and easy to install and operate. This is the reason shops are capable to provide service for the customers and customers are able to operate. A complex larger and more expensive product would not have such success.

General people with REB electrification use solar is for load shedding back up in houses. Only out of reach households use solar systems as primary electrification tool. Shops and business centers keep solar system as a load shedding backup as well. The general thought that solar systems usage save money is another contributor. Out of reach farms and fishing Gher, fishing boats etc. use solar for electrification. They primary use SHS as the demand of electrification is minimum and they do not have the technical space required nor the capital for a bigger system.

The open market is currently the number one supply point for users of SHS. Previously NGOs used to be sole affective supplier of products. Now as the products are successfully introduced commerce has taken

hold of the market. The shops in the market are able to provide good quality products in more acceptable rate. There are over 70 electronic shops in Khulna alone that sells solar products.

Open market receives the products from Nawabpur Dhaka. Here Bangladeshi companies and importers accumulate solar panels, batteries and other electronics related to SHS technology. Importers mainly import panels, converters and batteries from China. Local companies primarily focuses on battery and converter production.

Market proliferation of SHS product began with the hand of NGOs. Here many packages with installment options were offered to the general people. However with economic change within the polder region and a reliable supply chain opened the door for open market. From April 2016 Kajer Binimoy Khaddo (KaBiKha) and Test Relief (TR) included SHS within their donation program. At the beginning they used to acquire products from open market but after October 2016 they began to source only from NGOs.

4.1.3 Feasibility Analysis of SHS

In this section CPL research team has analyzed SHS against different feasibility sub-criteria and scored accordingly. CPL team here tried to determine against which feasibility sub-criteria SHS performs strongly or poorly. The team has assigned 'low/ medium/ high' scores against different sub-criteria on a basis of a scale of 1-3. Different weights were assigned against different criteria. Weights were put as per client priority and renewable energy expert suggestions. Detail calculations and weights are given in the Annex.

4.1.3.1 Technical Feasibility of SHS

The generation capacity is usually 80% of the PV capacity for the SHS; e.g. the generation capacity of a 40Wp system is 32W. The below table illustrate scenario of capacity vs utility level.

Table 4.1.3.1: PV capacity and utility level of SHSs

Capacity	Appliances	Operation
20Wp	3 W LED Lamp: 2 Mobile Charger: 1	4-5 hours
50Wp	3 W LED Lamp: 5 LED Color TV: 1 Mobile Charger: 1	4-5 hours
85Wp	3 W LED Lamp: 7 LED Color TV: 1 Mobile Charger: 1 12 W DC Table Fan: 1	4-5 hours

SHS has the limitation of load connecting cable length of 25feet to restrict the energy loss. Being low voltage supply, the current is higher in SHS which need thicker cable and in thicker cables, power drop is high. Solaric 3-G SHS also eradicate this limitation of conventional SHS.

To assure the quality of a photovoltaic power system and its correct functioning and guarantee costumers' satisfaction, it is important that the components of the system and the system as a whole meet certain requirements. The GIZ prepared a publication which gives an overview of different standardization

activities and existing standards that are relevant for solar home systems (SHS) and rural health power supply systems (RHS), titled “Technical Standards for Solar Home Systems (SHS)”².

Besides, before installing a photovoltaic (PV) SHS, its size has to be calculated according to different assumptions, such as measurement of solar radiation, solar insolation and power demand. Regarding the installation process, Solar Home Systems have to be installed by a trained technician who knows how to handle its different parts.

In the table below CPL has assessed technical feasibility of SHS against SAT framework prescribed criteria.

Table 4.1.3.2 Technology feasibility against Technical Criteria:

Technical Criteria	Facts/Findings	Performance (Low to high)	Score (1 to 10)
TC1. Compatibility with existing situation	Fully compatible	High	8
TC2. Output	Moderate output; loss due to thick wire and DC-DC converter	Medium	5
TC3. Energy Efficiency/ Performance	Moderate efficiency	Medium	5
TC4. Ease of Operation	Easy to operate	High	8
TC5. Extent of local materials/ resources use	Can be fabricated fully by local materials	High	8
TC6. Ease of Maintenance	Easy maintenance; quite low maintenance system	High	7
TC7. Substitutability	Easy substitutability	High	7
TC8. Durability or Longevity	System has several components with several durability factors; as a whole the system durability is medium	Medium	5

From the table above and also in the diagram beside (the spider diagram represents score/ performance against different technical criteria) it can be seen, this particular technology is fully compatible in off-grid areas under BG program zone. Energy output and energy efficiency are both medium. Any excess power generated due to bright sunshine or long hours of sunlight cannot be utilized and is therefore wasted. ‘

It is easy to install, operate and maintain. It has an already established value chain and users have easy access to sellers and after sales service providers.

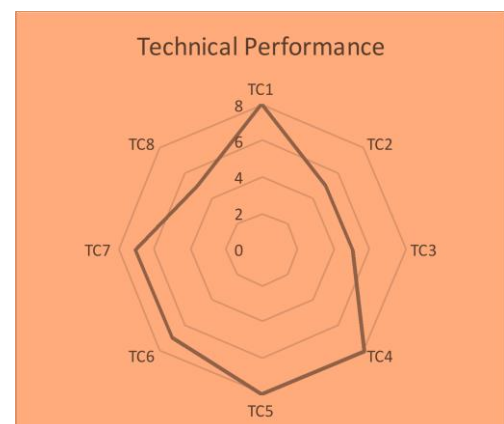


Figure 4.1.3.1: Technical feasibility of SHS

² [https://energypedia.info/wiki/Technical_Standards_for_Solar_Home_Systems_\(SHS\)](https://energypedia.info/wiki/Technical_Standards_for_Solar_Home_Systems_(SHS))

4.1.3.2 Social Feasibility of SHS

As a whole, SHS has created huge job opportunities through NGOs mainly. With declining SHS sales by NGOs, many of those are at stake now. Providing SHS under credit program created a huge market of loan as well. Actually Job creation was triggered by that. On the other hand, field study reveals that, sales of private sector selling SHS is increasing. Although exact data may not be available but it is now accepted that majority of the current SHS trade is done by local businesses for non-branded products. This increase of sales by the open market may become catalyst for new employment for the polder region.

In the table below CPL has assessed social feasibility of SHS against SAT framework prescribed criteria.

Table 4.1.3.2.: Technology feasibility against Social Criteria

Social Criteria	Facts/Findings	Performance (Low to high)	Score (1 to 10)
SC1. Acceptability within the local culture/ context	Accepted by the community	High	8
SC2. Extent of necessary resettlement and rehabilitation of people	Not required	High	8
SC3. Improvement of quality of life	SHS has limited usage level due to the low voltage DC output; so improvement of quality of life is medium	Medium	5
SC4. Occupational risks and hazards	Insignificant	High	7

From the table above and the spider chart besides it can be seen that, SHS has gained wide acceptability in the piloted areas as it is cheap and uses only solar energy as the energy source. It does not have any threat against occupational safety or health conditions. There is no need for resettlement and rehabilitation of people by the adoption of this technology.

SHS also has limited usage level due to the low voltage DC output; so improvement of quality of life by this system has been medium.

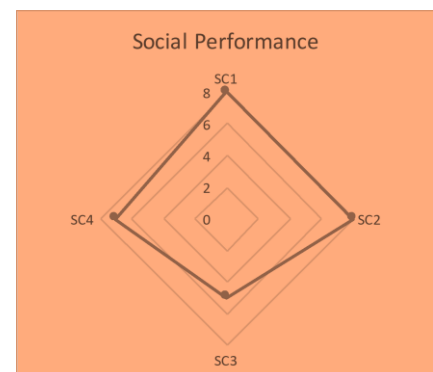


Figure 4.1.3.2: Social feasibility of SHS

4.1.3.3 Financial Feasibility of SHS

For financial feasibility analysis let us consider a 40Wp system whose generation capacity is 32W. The price of the product is BDT 18,500 if purchased in cash and BDT 21,000 in instalments. Now considering 9 hrs/day utility at 90% efficiency level (that could be the highest one in fact), per month the system can finally deliver around 8KwH (unit) of electricity. Considering BDT 30 per unit (as offered by Solar Mini Grid), monthly utility equivalent to BDT 234 can be achieved from the system. So annual benefit will be around BDT 3,000. Finally, the payback period would be more than 6 years. The price here has been considered from data provided by IDCOL.

During field visit it was also found that there are several non-branded or locally branded SHS available in the local market and there is a significant price difference between the NGO provided solution and those. Those are way cheaper and payback period would not be more than 4 years if those prices are considered. However, product quality of non-branded or locally branded SHSs may significantly differ.

In the table below CPL has assessed financial feasibility of SHS against SAT framework prescribed criteria.

Table 4.1.3.3: Technology feasibility against Financial Criteria

Financial Criteria	Facts/Findings	Performance (Low to high)	Score (1 to 10)
FC1. Capital investment	Low in scale but High in case of utility comparison (on an average BDT 580 per W)	Medium	5
FC2. Operation and maintenance costs	Low; (around BDT 15 per W per Yr)	Low	8
FC3. Benefits (energy, flexible payment, uninterrupted service)	Basic need of electricity can facilitate study and other essential household activities at night	High	8
FC4. Economic viability	Economically viable for off grid area considering opportunity cost BDT 30 /KwH	Medium	5

SHS is a significantly cheaper and cleaner alternative than diesel powered systems. Operations and maintenance costs are quite low as no raw material need to be fed into.

Considering opportunity cost of BDT 30 per unit (KwH) of electricity, Average annual benefit from an SHS unit was calculated around BDT 3,000. And the payback period was calculated as around 6 years whereas the product lifecycle is assumed to be 20 years.

4.1.3.4 Environmental Feasibility of SHS

Only the solar module is placed in an open space to be exposed to the sun; other components are placed inside the house. Installing solar module may require cutting some branches of trees to get full sunlight. This might be the single environmental consideration for SHS. It doesn't have any other environmental issue. The temperature raise for reflection is not significant as the solar panels are quite small (2sft- 8sft) for SHS. In the table below CPL has assessed environmental feasibility of SHS against SAT criteria.

Environmentally, the solar power technology has zero carbon footprint and moreover it can claim credit for lessen carbon emission (which could be generated by conventional methods). It consumes only solar energy. SHS also has low space requirement (e.g. 40Wp system it requires 4sft.).

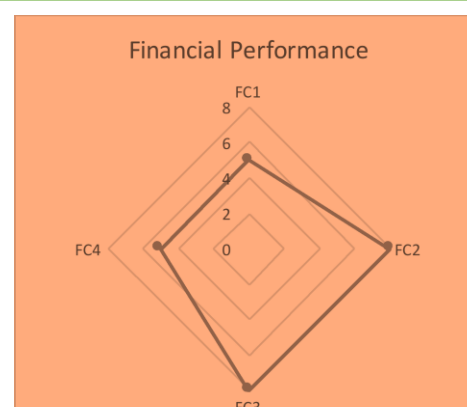


Figure 4.1.3.3: Financial feasibility of SHS

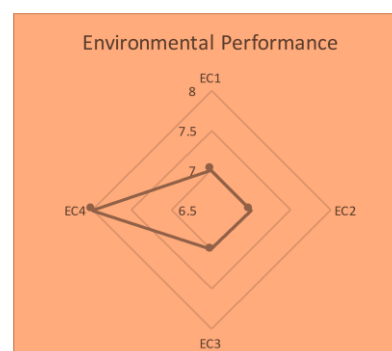


Figure 4.1.3.4: Environmental feasibility of SHS

Table 4.1.3.4: Technology feasibility against Environmental Criteria

Environmental Criteria	Facts/Findings	Performance (Low to high)	Score (1 to 10)
EC1. Land/ space requirements	Space requirement is low for a (e.g. 40Wp system it requires 4sft.)	High	7
EC2. Affecting biodiversity (ecology; crop, fisheries, etc.)	Only consumes solar energy	Low	7
EC3. Raw materials consumption	No raw material consumed by SHS	Low	7
EC4. Emissions	No CO ₂ emission (except instances when diesel generator runs)	Low	8

4.1.3.5 Overall Feasibility of SHS

Currently SHS is the most widely used renewable energy technology, used not only within the polder region but all around the country. As this technology is already widespread and a popular rural name, taking this technology to household level in polder area would be comparatively easier and less costly. At present open market actors hold the largest market share of SHS in polder areas. Although NGOs began the primary task of introducing the system to the public from early 2000, from 2014 the market shifted in favor of open market as the supply chain of SHS system became easily accessible by local businessmen and traders. From April 2016, KaBiKha (Kajer Binimoy Khaddo) and TR (Test Relief) programs began introducing SHS as a relief good. At that time, they purchased SHS units from open market but from November 2016 they began to acquire it from NGOs. Unfortunately, this has created a misleading idea among community members that SHS is a relief good and distorted level playing field for open market actors.

Table 4.1.3.5: SWOT Analysis for SHS

Strength	Opportunity
1. Moderate energy efficiency; provide cost-effective solution for supplying amenity power for lighting and small appliances 2. Easy to operate and maintain 3. Tested technology; technically durable 4. Environmental hazard free technology; socially acceptable 5. Low cost technology (low investment; low operational costs) 6. Small payback period 7. SHSs are generally accompanied by 20-year guarantees; POs have set up robust customer response teams	1. Established market channels 2. High acceptability among community members 3. The government allows companies to import solar panels free of duties, provides loans and grants to POs through IDCOL and even offers refinancing options 4. Companies that manufacture solar modules or those that use solar modules to contribute solar power to the national grid are privy to tax benefits and feed-in tariffs
Weaknesses	Threats/ Challenges
1. Limited energy output and efficiency; limited usage; low enterprise benefits 2. 6. Comparatively low NPV; moderate IRR	1. No potential threat could be identified

Currently, most users in polder areas use it for complete or partial electrification of Households and small business enterprises. Users within REB grid use SHS mostly during load shedding or natural disaster. Some households also use it alongside grid connection to reduce electricity cost.

As local and international suppliers of SHS technology is available, this technology has great business potential. Small rural businessmen could be inspired to open shops or service centers within the polder communities. This modality would compete with the open market located in nearby towns but cut down the problem of long distance travel for the people. This will also generate employment for many community people within the polder regions.

Alongside understanding different feasible aspects of the technologies, it is important to understand market dynamics, the usage and business potentiality of the technology within the polder regions. In next section we will discuss on these issues.

4.1.4 Target Market of SHS

Almost all the rural households in the polder regions can be users of SHS technology (even on-grid households as there are concerns about the quality of electrification). Rationale behind this is that SHS is a small portable system that can be easily set up and does not require much space or high level of maintenance. It requires very small amount of investment and now also available as relief good by KaBiKha and TR in polder areas. The target market can also be classified into two broader categories.

4.1.5 User and Usage of SHS

Primary users of SHS systems within the polder regions can be divided into two broader categories. First would be users with REB grid support and the second would be users out of reach of REB grid support. Each of them can be further divided into household level users and rural enterprises.

Table 4.1.5: User and Usage of SHS within the polder regions

On-Grid	
Households	Households within the REB electrification grid primarily use SHS electrification as backup for load shedding. They are also a reliable source of power during natural disaster. And the usage of solar power reduces cost.
Rural Enterprises	Many shops, Farms, workshops, fishing ghers with REB electrification use SHS electrification as a backup during load shedding. For example, poultry farms require at least 16-hour light per day. For them load shedding and natural disaster may cause massive financial loss. Thus they rely on solar power as a backup. The use of such system is also considered as a cost reduction choice. Some activities done by such enterprises do need constant electrification.
Off-Grid	
Households	Households outside the reach of REB grid coverage use SHS power as their sole electrification source. Here basic need of light and charging of a mobile phone are generally met by SHS.
Rural Enterprises	Many shops, Farms, workshops, fishing ghers outside REB electrification use SHS electrification as a primary source of power. Farm houses deep within the fields cannot access

The utility of SHS is limited as it provides low voltage DC current. Some DC appliances (e.g. DC fan) has been popular mainly due to compatibility with SHS. However, one model of Solaric namely 3G-SHS (3rd Generation Solar Home System) includes an Optimizer which converts 12V DC to 125 DC supply which is compatible with standard appliances; thus widen the usage and application of SHS. Due to low in capacity, SHSs are focused to address the basic needs of electricity. Though the system is uninterrupted in nature, due to less capacity, SHS can't ensure uninterrupted supply at its full capacity as part of its capacity recharge the storage i.e. battery.



Figure 4.1.5: Application of Solar Home System

On the whole, they contribute to the improvement of the standard of living by reducing indoor air pollution and therefore improving health as they replace kerosene lamps, providing lighting for home study, giving the possibility of working at night, facilitating the access to information and communication (radio, TV, mobile phone charging), etc.

Two case studies on application of solar panels in powering households and rural businesses like poultry farms are presented below.

CASE STUDY: Solar Panels Powering Homes

Mrs. Lucky has been living with her family in Baitaghata, Khulna. She works as a day laborer along with her daughter. They live in small shanty houses by the Rupsha River. Although the region is connected by REB electrification, but because of the location her house is not connected. Because of her work in KaBiKha she received 85 watt SHS system. Before that her daughter purchased a 20-watt system from RSF. Now they use both the systems for electrifying their home.



Figure: Deserted RE Electrification System

These systems light their bulbs and charge her mobile phone. They find the systems simple to operate and maintain. Living under harsh realities SHS provides vital support for the family.

CASE STUDY: Solar Panels Powering Rural Business



Figure: SHS in powering Poultry Farm

Mr. Aravinda has been in the poultry business for over 20 years. He has two poultry farms in valuka chadpur, Satkhira. He built a new poultry facility at the end of 2015 which however is located at a place which is out of reach of the grid connection by REB. As a result, he has been lighting the required fifty bulbs of his poultry farm using solar panels. The system costed him around 25,000 tk. He bought it from the local market rather than from an NGO as it was cheaper. He claims that such a system from NGOs would cost him around 50,000 tk.

During egg laying time he has to keep the lights on for 16 hours daily. He uses 130 Ah Battery and 140 Watt solar Panel. He did not see anybody else in his region doing poultry business using solar power. He claims that he took a good business decision as solar power is more cost effective and serves his purpose.

4.1.6 Business Model Attributes and Requirements for SHS

Table 4.1.6: Business Model Attributes and Requirements for SHS

Potential Service Areas	- Off-grid Polder areas - Polder areas that are connected to the grid but suffers from load-shedding
Business model type	The usual financial terms that entities like Grameen Shakiti (GS) or BRAC has introduced for its product: ▪ The user has to pay 15% of the total price as down payment. The remaining 85% of the total cost is to be repaid within 36 months with 6% (flat rate) service charges. ▪ The customer has to pay 25% of the total price as down payment. The remaining 75% of the cost is to be repaid within 24 months with 4% (flat rate) service charge. ▪ Micro-utility : The customer has to pay 10% of the total price as down payment. The remaining 90% of the loan amount is to be repaid by 42 cheques. There is no service charge. ▪ 4% discount is allowed on printed price in case of cash purchase.
Potential Development Partner(s)	- IDCOL (fund from GIZ, KfW, ADB, IDB, GPOBA, JICA, USAID and DFID; IDCOL has a target to finance 2 million more SHS by 2017) - Local level POs of IDCOL who can take loan from IDCOL

Potential Private Partners	- Gramen Shakti; BRAC; Rahimafrooz Solar; Rural Services Foundation (RSF) - Some local machinery workshops, manufacturers and SMEs have also assembled and developed their local SHS versions and been marketing those through local market networks.
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At present SHSs are produced, demonstrated, distributed and marketed by different public, private and development actors around the world. Global sales service providers like Alibaba and Amazon have been selling SHSs of different capacities sourcing from different manufacturers worldwide. Grameen Shakti has been the largest organization installing rural based solar home system (SHS) in Bangladesh. GS has developed an effective strategy for reaching people in remote and rural areas with solar PV technology. Their service package involves soft credit through installments which makes SHSs affordable, advocacy and promotion, community involvement and social acceptance and after sales services.

Although the solar panel's cost-per-watt peak has declined in recent years, the price of a solar home system still remains out of reach for millions of rural Bangladeshis. Therefore, entities like EnDev (Energizing Development) Bangladesh has been working with its partners to develop an approach to create a conducive market environment for even smaller solar systems to meet the basic lighting needs of even poorer households. These Pico PVs (solar lanterns), with panel sizes of less than 10 Wp, use efficient LED technology to ensure maximum light output from a small amount of energy. Lithium based batteries with a capacity to run the lights make these products environmentally clean and reliable also in the rainy season, where sunlight levels can remain low for a number of days.

Rahimafrooz Renewable Energy Ltd. (RREL), is one of the pioneering solar companies in Bangladesh in solarizing this country. They specialize as a systems integrator & installer of solar solutions and manufacturer of key solar components. RREL has established a fully automated PV module manufacturing plant with a capacity of 18MW, which caters not only captive requirements, but also supplies to other similar organizations and exports abroad. As of date RREL has so far installed more than 25 MWp of solar system in forms of Solar Home System (SHS), solar pumping solutions, telecom solutions, and on-grid rooftop solutions and decentralized solar community electrification projects etc. Different SHS related service packages of Rahimafrooz are given below³:

	LED Tube	LED Bulb	Battery	Panel
20Wp	5W 500Lu; 3W 300Lu	2W 120Lu	15AH Tubular Deep Cycle Battery; 10hrs	20Wp crystalline PV module
30Wp	5W 500Lu; 4W 400Lu	2W 120Lu	23AH Tubular Deep Cycle Battery; 10hrs	30Wp crystalline PV module
45Wp	7W 700Lu; 5W 500Lu; 4W 400Lu; 3W 300Lu	-	30AH Tubular Deep Cycle Battery; 10hrs	45Wp crystalline PV module
50Wp	7W 700Lu; 5W 500Lu; 4W 400Lu; 3W 300Lu	-	30AH Tubular Deep Cycle Battery; 10hrs	50Wp crystalline PV module
70Wp	7W 700Lu; 5W 500Lu; 4W 400Lu; 3W 300Lu	-	55AH Tubular Deep Cycle Battery; 10hrs	70Wp crystalline PV module
90Wp	7W 700Lu; 5W 500Lu; 4W 400Lu; 3W 300Lu	-	55AH Tubular Deep Cycle Battery; 10hrs	90Wp crystalline PV module

³ <http://www.rahimafrooz-solar.com/index.php/product-and-services/2014-03-22-06-51-07/solar-home-system-shs>

4.2 Solar Nano Grid (SNG)

4.2.1 Background

The principle of 'electricity for all' is mainly based on balancing the energy demand and generation annually. Balancing the demand and generation requires two pronged approach. The first is to work out strategies for building higher energy efficiency appliances for rural households. The second is to promote renewable energy technologies like solar and wind, biogas and bio-fuel, etc. Due to the ever-increasing demand, government authorities like BPDB will have the challenge for long.

In purpose of the balancing as a part of the mandate 'electricity for all', Solar Mini Grid (SMG) of distribution systems has been developed and implemented, to augment the renewable sources with the local loads. Maintaining the balance of demand and generation in such a Mini Grid is challenging, because of the huge initial investment, and the difficulty in keeping the system variables within the limits.

The situation can be improved by a more compatible system to balance demand and generation in a smarter way and thus Solar Nano Grid (SNG) came into light. This takes advantage of the fact that houses are frequently clustered together in rural areas in groups of 40-50 houses within a diameter of less than 500m. In the Nano-grid system, a basic 1.5 to 3 Kwp PV system is installed in a small cluster of households within a short radius of each other (ideally 230-250m)



Figure 4.2.1: Solar Nano Grid

can address the problem of limited functionality associated with independent Solar Home System. The Nano Grid system is also expandable as per the energy need of the community.

Within this context, the nano-grid concept is based on the idea of the SHS, where the basic electricity needs of the households are met, but at the same time it proposes the incorporation of some small scale agricultural, business or industrial applications. For the solar-nano-grid, any excess power generated from the central location, can be effectively utilized for small commercial or industrial needs like shops, cottage industry, irrigation etc.

Solar Nano Grids can be designed to improve food security, reduce indoor air pollution, raise productivity of natural resources, and enhance conservation landscapes by reducing exploitation of natural resources.

4.2.2 Demand and Supply Situation of SNG

SNG is not yet a popular or renowned RE technology and not a shelf product of rural shops or enterprises alike SHS. Few rural households in polders areas were found to be aware about the application and benefits of selected technology. Although the technology is not complex enough to deter users, we did not see prominent examples of SNG used in our visits in the sample polder areas. Local enterprises or traders involved with SHS business also are not involved with SNG trade. The root cause of this could be identified as popularization SHS system.

But with increasing income and business opportunities in polders areas, their energy demand is also increasing. Therefore, 24 hour electrification for households and SMEs from SNG could be a viable solution for polder areas. This takes advantage of the fact that houses are frequently clustered together in rural areas in groups of 40-50 houses. Initial investment is comparatively smaller and local SMEs or entrepreneurs can invest in it and provide electrification service to rural households and SMEs with profitable outcome for both parties.

Just like SHS, the supplier of SNG technology can be traced back to open market and NGOs. At present NGOs are successfully involved in most of the SNG systems operating in Bangladesh. As the current market leader for SHS, open market can be strengthened to supply for SNG systems in polder areas.

4.2.3 Feasibility Analysis of SNG

In this section, CPL has analyzed SNG against different feasibility sub-criteria and scored accordingly. The team tried to determine against which feasibility sub-criteria SNG performs strongly or poorly. 'low/ medium/ high' scores against different sub-criteria on a basis of a scale of 1-3 were assigned. Different weights were assigned against different criteria. Weights were put as per client priority and renewable energy expert suggestions. Detail calculations and weights are given in the Annex.

4.2.3.1 Technical Feasibility of SNG

As the technology has provision of scaling up, one 1Kwp system can be gradually upgraded to a 3Kwp system based on the growth of load. But to ensure the future expansion, initial design should consider the upgradation option and keep provision in the infrastructure (keeping space in battery bank, rooftop solar array, cable tray and circuit breakers etc.). Maintenance of the system is easy and completely at the service provider end. Underground cabling ensures less maintenance of distribution system.

A nano-grid has to reflect needs of the people and consider aspects like energy needs, space availability, cluster options, location and local contexts, possible business model, etc. in order to ensure long-term sustainable improvements to wellbeing can be achieved. Therefore, experts need to be involved during nano-grid system design for a particular community.

In implementing a solar-nano-grid, there are a number of factors to consider. One influencing factor is the variation of population density in a cluster and therefore the layout of the nano-grid must be different for efficient operation or design.

Because population density is quite high in Bangladesh (and also in the BG program area), the power-generating unit of a nano-grid system can be placed in a central position and power distribution can be done by short radial feeders running between each household and the generating unit. As a result, there will be less line drop, less power loss in the line and overall system efficiency will be high.

In the table below, CPL team has assessed technical performance of SNG against SAT framework prescribed criteria.

Table 4.2.3.1: Technology Feasibility against Technical Criteria:

Technical Criteria	Facts/Findings	Performance (Low to high)	Score (1 to 10)
TC1. Compatibility with existing situation	Fully compatible	High	8
TC2. Output	Good output as flexible conversion and high voltage DC power	High	7
TC3. Energy Efficiency/ Performance	Better efficiency than the other grid options (load factor 0.55)	High	8
TC4. Ease of Operation	Easy to operate; but needs preliminary training on operation procedures	High	8
TC5. Extent of local materials/ resources use	At present imported materials are being used mostly; but can be fabricated fully by local materials	High	8
TC6. Ease of Maintenance	Easy maintenance; but needs preliminary training on maintenance	High	7
TC7. Substitutability	Substitutability is uncertain	Medium	6
TC8. Durability or Longevity	System has several components with moderate durability factors; as a whole the system durability is medium	Medium	5

In the table above and also in the diagram beside (the spider diagram represents score/ performance against different technical criteria), this can be seen that this particular technology is compatible with off grid areas under BG program zone. Output efficiency is quite impressive. Besides meeting household needs, at the same time it also proposes electricity for some small scale agricultural or industrial/ business applications. Once installed, the system is comparatively easy to operate and maintain, but preliminary training is needed on operations and maintenance. Besides, SNG has ability to withstand wear, pressure, or damage in the long run.

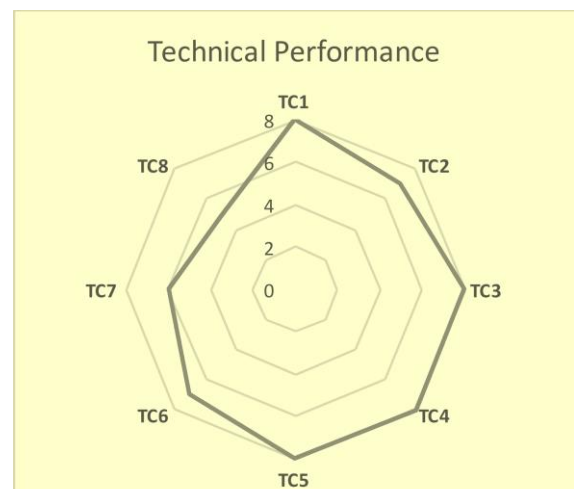


Figure 4.2.3.1: Technical Feasibility of SNG

A SNG system for a community should reflect several technical and socio-economic factors in its design, like specific needs of the community people, energy needs, space availability, clustering options, location and local contexts, possible business model, etc. Therefore, experts need to be involved during nano-grid system design and installation for a community.

4.2.3.2 Social Feasibility of SNG

Because SNG can generate enhanced output capacity and can serve the purpose of small scale agricultural, business or industrial applications, SNG has the potential to create direct job opportunities for large number of people in polder areas. Also, local entrepreneurs of polder areas can invest in it and become

rural electrification service providers. The payment method for the consumer can be 'pay per unit of energy' or 'use as you pay' modality which give HHs multiple payment options.

In the table below CPL has assessed social feasibility of SNG against SAT framework prescribed criteria.

Table 4.2.3.2: Technology Feasibility against Social Criteria

Social Criteria	Facts/Findings	Performance (Low to high)	Score (1 to 10)
SC1. Acceptability within the local culture/ context	Good acceptability in piloted communities; it has had significant impact in improving quality of life in societies	High	8
SC2. Extent of necessary resettlement and rehabilitation of people	The facility or location is selected through survey; resettlement or rehabilitation is usually not necessary, but sometimes space/ land has to be rented	High	7
SC3. Improvement of quality of life	Significant	High	8
SC4. Occupational risks and hazards	The technicians are trained on safety; no exposure of significant hazards	High	7

This can be seen, SNG has gained good acceptability in the piloted areas as it has had significant impact in improving quality of life in societies. This technology had significant impacts on livelihood in areas that were not connected to grid. It does not have any threat against occupational safety or health conditions.

The facility or location is selected through survey, and therefore resettlement or rehabilitation is usually not necessary, but sometimes space/ land has to be rented. Besides, this technology has good level of job creation opportunity.

Solar Nano Grid can significantly improve food security situation in the targeted community, reduce indoor air pollution, raise productivity of natural resources, and enhance exploitation of natural resources.

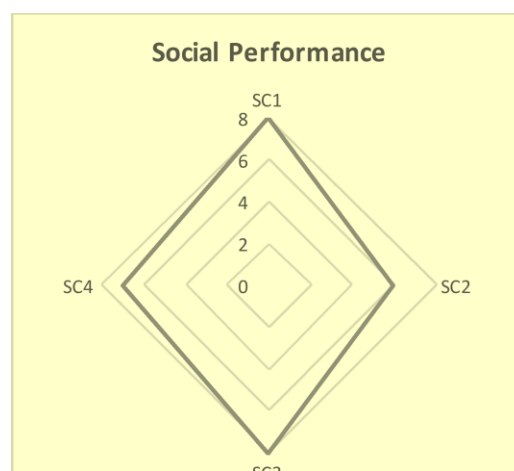


Figure 4.2.3.2: Social Feasibility of SNG

4.2.3.3 Financial Feasibility of SNG

Per expert opinion, a 3Kwp SNG would require a capital investment of roughly BDT 900,000. A financial package by IDCOL (50% grant, 30% loan at 6% interest, 20% equity) has been the source of investments so far. Project lifecycle has been assumed to be 10Yrs. in a discounted rate of 10%. In case of loan, 9% bank rate is assumed (considering green financing option).

Based on the assumptions and projections, the project IRR is calculated as 19.8 whereas equity IRR is 35.7 for a 3Kwp SNG (see detailed calculations in Annex).

In the table below CPL Team has assessed financial feasibility of SNG against SAT framework prescribed criteria.

Table 4.2.3.3.3: Technology Feasibility against Financial Criteria

Financial Criteria	Facts/Findings	Performance (Low to high)	Score (1 to 10)
FC1. Capital investment	Moderate (a 3Kwp SNG requires investment of roughly BDT 900,000)	Medium	5
FC2. Operation and maintenance costs	Operations and maintenance costs are low as no raw material is needed to be fed into	High	8
FC3. Benefits (energy, flexible payment, uninterrupted service, enhanced biodiversity)	Energy output and energy efficiency is quite high; basic need of electricity can facilitate essential household activities at night	High	8
FC4. Economic viability	Economically viable for off grid area in a service modality	High	7

Apart from the capital expenditure, BDT 108,000 has been calculated as the annual operations and maintenance. Detail cost-benefit breakdown is given below.

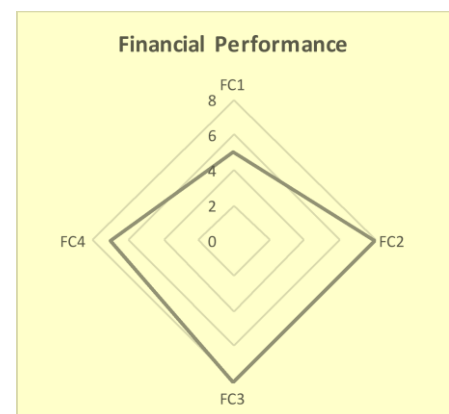
Table 4.2.3.3.1: Operational and maintenance costing for a SNG

Monthly Maintenance Cost (BDT)	5,000.00
Annual Maintenance Cost (BDT)	60,000.00
Monthly Operational Resource Cost (BDT)	4,000.00
Annual Operation Cost (BDT)	48,000.00
Annual O&M costs (BDT)	108,000.00

Income has been calculated based on the utilization of the system as it focuses utility and unit price has been BDT 30/Kwh.

Table 4.2.3.3.2: Income from a SNG

PV Capacity (Kwp)	3.00
Generation Capacity Kw (80%)	2.40
Load Factor for Unrestricted Usage	0.55
Steady Output (KwH)	1.32
Per day generation unit (KwH)	31.68
Unit Price (BDT)	30.00
Per day income (BDT)	950.40
Annual Income (BDT)	346,896.00



4.2.3.4 Environmental Feasibility of SNG

Ideally the distribution is facilitated by underground cabling in SNG. So the system would not be appropriate for areas submerged in water or waterlogged areas. Also by design SNG focuses cluster of HH in a proximity (within a radius of 250M), so there should be spaces or walkways in between the HH so that underground cabling can be done.

In the table below CPL has assessed environmental feasibility of SNG against SAT framework prescribed criteria.

Table 4.2.3.4: Technology Feasibility against Environmental Criteria

Environmental Criteria	Facts/Findings	Performance (Low to high)	Score (1 to 10)
EC1. Land/ space requirements	space requirement is low for a (e.g. 1200sft for a 3Kwp system)	High	7
EC2. Affecting biodiversity (ecology; crop, fisheries, etc.)	No significant short term or long term affect	High	7
EC3. Raw materials consumption	No raw material consumed except solar energy	High	7
EC4. Emissions	No carbon footprint	High	8

SNG does not pose any threat or risk to its users or environment. It does not have any carbon footprints as it is solely run by solar energy. And the system has shown good resilience against climatic factors.

Space requirement for this facility is also comparatively low (e.g. 1200sft for a 3Kwp system).

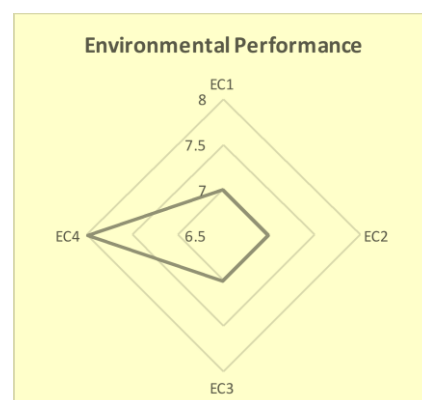


Figure 4.2.3.4: Environmental Feasibility of SNG

4.2.3.5 Over all Feasibility of SNG

From above sections this can be seen that SNG has greater technical, social, financial and environmental feasibility and can be used in wider variety of rural applications. Capable businessmen, entrepreneurs and SMEs can set up an SNG system and can sell electrification service to clusters comprising households, farmers, shops and SMEs at markets. The system on rural areas can also be diverted towards electrification of irrigation pump thus serving another important purpose. The demand for this system yet may not be high but its service potential and demand will grow if more awareness of its benefits can be created within polder regions.

The following matrix describes strengths, weaknesses, opportunities and challenges or threats of installing SNG system under rural context. CPL team has identified that, proper maintenance and efficient service provision model need to be planned and deployed; otherwise, project might not be sustainable.

Table 4.2.3.5: SWOT Analysis of SNG

Strength	Opportunity
1. A groups of 40-50 houses and shops/ enterprises within a diameter of less than 500m can be connected to a single SNG unit 2. High energy efficiency and output performance (Nano-Grid's electricity can also about 50% cheaper than diesel fuel) 3. Energy output can be used for meeting household needs and small enterprise needs simultaneously 4. Tested technology; Compatible with existing energy requirements 5. Management System is compatible; easy to operate and maintain 6. Environmental hazard free technology; socially acceptable 7. High NPV, High IRR, small payback period 8. Scalable at all levels (DC, High Voltage; just adding in parallel; no synchronization needed any standard load can be used)	1. Rural enterprises will be benefited 2. Economically viable for off grid area in a service modality 3. High acceptability among community members 4. Growing service market (importers, engineers; distributors)
Weaknesses	Threats/ Challenges
1. Moderate to high initial investment (a 3Kwp SNG requires investment of roughly BDT 900,000)	1. Proper maintenance and efficient service provision model need to be developed

4.2.4 Target market for SNG

SNG similar target market like SHS. But with increased output and broader application range, rural SMEs and households that demand enhanced energy output might also be potential target market for SNG. However, the target market need to be closely clustered households and business centers (rural market places, shops and workshops).

4.2.5 Usage of SNG

Enhanced energy output has given SNG the privilege to serve a wide range or rural customers across a wide range of applications. However, the technology itself is designed to cater to a larger number of people in close proximity which means it cannot be established on remote individual positions (Fishing boats, fishing ghers, etc.).

Table 4.2.5: User and Usage of SNG within the polder regions

On-Grid	
Households	Close-knit households within the REB electrification grid primarily can use SNG electrification as backup for load shedding. This can be also a reliable source of power during natural disaster. The SNG electrification can also play a major role in cost reduction.
Rural Enterprises	Close-knit shops and workshops of village market with REB electrification can use SNG electrification as a backup during load shedding.
Off-Grid	
Households	Close-knit households outside the reach of REB grid coverage use solar power as their sole electrification source. Here basic need of light and charging of a mobile phone are generally met by SHS.
Rural Enterprises	Close-knit shops and workshops of village market without REB electrification can use SNG electrification as their primary source of electrification.

The great advantage of SNGs over other technologies (usually household-focused) is that they do not solely focus on individual households, but also bring additional collective community benefits. Having both options of high voltage DC (220V) as well as AC (220V) supply, the system offers a full range of utility for HH appliances. Unlike SHS the usage of standard appliances (e.g. computer) is not restricted for this system. This can also power small irrigation pumps. Scaling up the generation based on demand (load) can be done easily by adding PV system (solar panel) in parallel.

By providing clean energy this way, SNGs can improve quality of life, empower women, improve health, increase children's educational attainment, and boost the local economy. Nano-Grid's electricity can also about 50% cheaper than diesel fuel, which is what many people use in Bangladesh.

Additional collective community benefits can be achieved by the establishment of village energy committees, and the implementation of training programs for the better management of the systems over their lifetime.

General features of SNG are briefed below:

1. Scalable at all levels (DC, High Voltage)
2. Starting load could be small to reduce the cost of installation and then scale up as the load grows
3. Unlike AC grid, scaling up the generation is simple. No synchronization required
4. Any standard load can be used
5. No maintenance is necessary by end customer
6. Pre-paid meter makes collection significantly easy
7. Can support commercial applications like irrigation for farming

4.2.6 Business Model Attributes and Requirements for SNG

Table: 4.2.6 Business Model Attributes and Requirements for SNG

Potential Service Areas	- Polder areas that are not connected to the grid - Polder areas where there is lack of access to electricity for small and medium business and agricultural purpose
Business model type	- Community/ Cluster based business model - A large PV installation can serve 40-50 households/ shops within 500m diameter; or a smaller PV installation can serve 15-20 household cluster - A local investor could pay for part of a Nano-Grid system and then make about BDT 10,000 a month by selling electricity to 40-50 homes locally - Pre-paid meter can be installed at customer level - Users connected to SNG can sell electricity to other villagers (for battery charging, etc.)
Potential Development Partner(s)	- IDCOL (50% grant, 30% loan at 6% interest, 20% equity)
Potential Private Partners	- SOLARIC (Solar Intercontinental Ltd)

4.2.7 Inclusive business service options

In nano-grid system, a basic 1.5 to 3 kilowatts peak PV system is installed in a small cluster of households within a short radius of each other (ideally 230-250 metres) and power is distributed to the households from the system. The generation and storage of the system is 48 volt DC. With SNG, the cost per light per month is only Tk 20 against Tk 120 for kerosene lamps.

In principal SNG focuses on a utility level and hence doesn't concentrate on unit consumption rather value against delivered services. For example, monthly payment of BDT 100 is set for one light 6 hours a day or one mobile charging 50 taka per month. This also encourage the users to use energy efficient appliances rather cutting their need of usage. Pre-paid meter makes collection significantly easy. Having a better load factor, SNG is suitable for business in a service delivery modality.

Owing to the excess power generation of a solar-nano-grid, people from the nearby areas can come to the distribution points to charge their batteries, to collect water and to carry out other essential day to day activities of the community. Therefore, shops in the markets powered by nano-grids can also sell electricity (low watt applications; like battery charging) to villagers outside the grid coverage.

Local people can also invest in a Nano-Grid system and make money by selling power to other villagers for a monthly fee. In other words, an investor could pay for part of a Nano-Grid system and then make about BDT 10,000 a month by providing electricity to 50 homes locally. In such a case, villagers would not be paying a large corporation; they would pay a local person who managed the Nano-Grid.

Based on IDCOL type financing (50% grant, 30% loan at 6% interest, 20% equity), the tentative energy price is⁴ -

- For Households – USD 0.35/Kw-hr
- For irrigation – USD 0.19/Kw-hr
- Meter charge USD 2.5/month
- Average bill per household per month – USD4.4
- Average irrigation energy cost per season–USD87.5
- (less than 10% of the price of crop produced)

4.3 Solar Irrigation Pump (SIP)

4.3.1 Background

Agriculture plays an important role in Bangladesh's economy and employs 45 percent of the country's workforce. Water has been a critical lifeline for farmers as a day without proper irrigation can damage crop quality and yields. Farmers mostly use irrigation pumps to ensure water supply for their crops but incur substantial costs to purchase diesel fuel. Traditionally, Bangladeshi farmers have relied on expensive diesel- or electricity-powered irrigation pumps. There are 1.34 million diesel pumps and 270,000 electric-run pumps used for irrigation. Every year, diesel pumps consume 1 million tons of diesel worth \$900 million. This is a costly amount, which the government subsidizes at the expense of other agricultural innovations. Diesel pumps also frequently break down, have high maintenance costs, and pollute the environment. The minority of farmers, fortunate enough to own electricity-run pumps, also faces persistent power outages. This forces them to operate their pumps at night when electricity consumption decreases and power failures are less likely.

CPL also found this fact true for BGP areas as agriculture has been their main income generating sector and irrigation is a crucial component for the agro producers. That is why solar-powered pumps can be a reliable irrigation alternative for farmers as solar technology helps reduce costs, protect the environment, and lower expensive diesel fuel imports.

Solar irrigation pumps (SIP) can be used in remote polder areas where the cost of running traditional water piping or diesel pump is cost prohibitive or farmers are needed to provide water with off-grid solution. It enables its users to move water from its remote source to where they need it, without access to power lines. A solar pump can be connected to a PV-direct, powering the pump directly off the solar panel (through an inverter where AC motor is used), without using batteries.

Compared to their diesel counterparts, these pumps are also more reliable and easier to maintain. Scaling up solar-powered irrigation will also save foreign exchange significantly. Farmers in different pilot area (under different development project areas) have been switching from diesel-run to solar irrigation pumps. Some local manufacturers have also emerged who have been producing SIP using/ assembling locally available equipment. By reducing irrigation costs, solar pumps are becoming popular, especially in areas without electricity grid coverage.

4.3.2 Demand and Supply Situation of SIP

Although SIP has been tested and piloted in different areas of Bangladesh, mostly under different developed projects, we did not see prominent examples of SIP in our visits in the sample polder areas. Local enterprises or traders involved with SHS business also are not involved with SIP trade.

But agriculture being the major income generating source for the agro producers in BGP areas, increasing irrigation demand and high fuel price can make SIP a potential RE technology in near future. Solar-powered pumps can be a reliable irrigation alternative for farmers as solar technology helps reduce costs, protect the environment, and lower expensive diesel fuel imports.

Initial investment is comparatively smaller for SIP. Besides, local small entrepreneurs can invest in it and provide irrigation service to community farmers with profitable outcome for both parties. Just like SHS, the supplier of SIP technology can be traced back to open market and NGOs. As the current market leader for SHS, open market can be strengthened to supply for SIP systems in polder areas.

4.3.3 Feasibility Analysis of SIP

In this section, CPL has analyzed SIP against different feasibility sub-criteria and scored accordingly. Study team tried to determine against which feasibility sub-criteria SIP performs strongly or poorly. 'low/ medium/ high' scores against different sub-criteria on a basis of a scale of 1-3 were assigned. Different weights were assigned against different criteria. Weights were put as per client priority and renewable energy expert suggestions. Detail calculations and weights are given in the Annex B.

4.3.3.1 Technical Feasibility of SIP

Two SIP systems of two different capacities have been found in field visits having the following attributes presented below:

Table 4.3.3.1: Attributes of two Solar Irrigation Pumps

System Capacity/ Load	9.2 Kw	15.0 Kw
PV Capacity	15 Kwp	22Kwp*
Motor Type	3 Phs AC Motor	3 Phs AC Motor
Peak Water Discharge/ Day	1,000,000 Lit	1,400,000 Lit
Irrigation Area Covers	19.8 Acre	26.4 Acre
Raiser Points	9	10
Installation space required (sft)	4,356	6,534

**The study found 20Kwp PV in a 15Kw system at Chuadanga whereas 22Kwp PV in the same system at Kushtia (calculation is done up to 75% output level).*

SIP can be a very attractive alternative to diesel powered pumping and support sustainable agriculture. SIP can also complement the design of drip irrigation systems, delivering water precisely and efficiently to individual plants. High volumes of water for large scale irrigation can also be supported through a wide range of pump sizes and vertical lifts.

No storage or backup system is integrated with SIP which made it a simpler and cheaper solution. But the energy efficiency of the existing SIP at fields are low; hence energy loss is high. In the table below CPL has assessed technical feasibility of SIP against SAT framework prescribed criteria.

Table 4.3.3.2: Technology Feasibility against Technical Criteria:

Technical Criteria	Facts/Findings	Performance (Low to high)	Score (1 to 10)
TC1. Compatibility with existing situation	Management system is compatible; technology is tested; compatible with overall situation	High	7
TC2. Output	Good output performance	High	7
TC3. Energy Efficiency	High energy efficiency	High	9
TC4. Ease of Operation	Easy to operate; but requires relevant training	High	7
TC5. Extent of local materials/ resources use	Though in many cases imported solar cell and electrical parts are being used, locally produced quality products are available; construction materials are local	Medium	6
TC6. Ease of Maintenance	Easy to maintain; but requires relevant training	High	7
TC7. Substitutability	Easy to substitute other/ existing technology	High	8
TC8. Durability or Longevity	Has ability to withstand wear, pressure, or damage in the long run	High	7

As can be seen in the table above and also in the diagram beside (the spider diagram represents score/ performance against different technical criteria), this particular technology can be constructed using locally available materials. Though in many cases imported solar cell and electrical parts are being used, locally assembled and produced products are also available. This technology is easy to operate and maintain, and has moderate level of energy output. Energy efficiency is quite high as only solar energy is used.

Local expertise is available for regular operations and maintenance; but for analyzing and enhancing efficiency and designing optimized usage of resources, the study found that only local expertise might not be enough. Skill development and capacity enhancement trainings should be provided to the persons/ market actors responsible for SIP operations and maintenance. It also has a good performance track record in different areas since installations. Besides, SIP was found to be compatible with natural conditions of BG program area and also with existing infrastructure situation. Also, this technology seems to be highly adaptable to future situations.

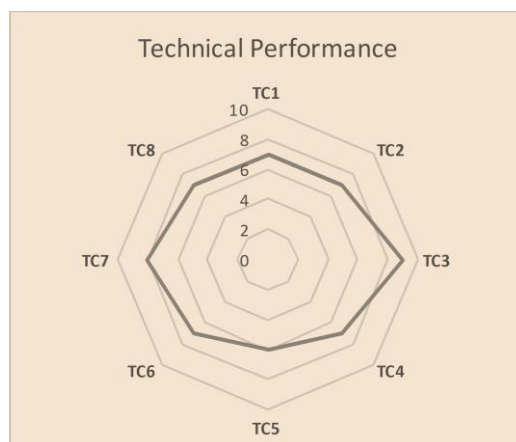


Figure 4.3.3.1: Technical Feasibility of SIP

4.3.3.2 Social Feasibility of SIP

Job creation potential is good as local irrigation service providers can be developed in polder areas. Our study found that around one supervisor is required for maintaining (operations and management) eight pumps in a close proximity (RDF implemented pumps, Mirpur, Kushtia). The solution is socially accepted as it is noise free and reduces fuel cost significantly. Inhabitants and associated farmers were found happy about the service quality and price.

In the table below CPL has assessed social feasibility of SIP against SAT framework prescribed criteria.

Table 4.3.3.2: Technology Feasibility against Social Criteria

Social Criteria	Facts/Findings	Performance (Low to high)	Score (1 to 10)
SC1. Acceptability within the local culture/ context	Good acceptability as it is a silent, smoke free and low cost solution	High	7
SC2. Extent of necessary resettlement and rehabilitation of people	Local irrigation service providers can be created	High	7
SC3. Improvement of quality of life	Less pollution and decreased cost create better life	High	7
SC4. Occupational risks and hazards	Safe and hazard free solution	High	8

This can be seen (the spider diagram beside represents score/ performance against different social criteria), SIP has gained high acceptability in the piloted areas as it is a silent, smoke free and low cost solution. This technology improves quality of life especially in areas where access to irrigation water has been a problem. It does not have any threat against occupational safety or health conditions and users do not need to take significant measures for resettlement and rehabilitation after adoption. However, this technology has limited job creation opportunity (around one supervisor is required for maintaining (operations and management) eight pumps in a proximity).

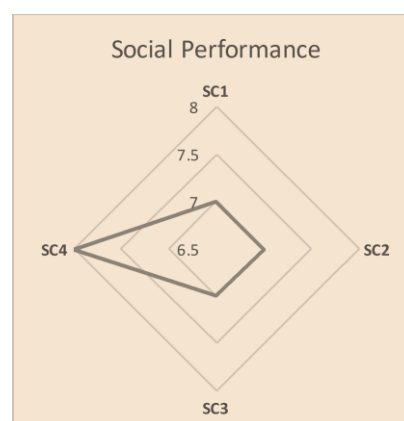


Figure 4.3.3.2: Social Feasibility of SIP

The solar pump and the amount of solar panels needed both depend on how many gallons per day (GPD) or gallons per minute (GPM) user wants to pump and the vertical head the pump needs to overcome. Therefore, it is crucial to select the appropriate type and size of solar pump. Besides, skill development and capacity enhancement trainings should be provided to the persons/ market actors responsible for SIP operations and maintenance in a community based model.

4.3.3.3 Financial Feasibility of SIP

From field investigation, it has been found that the farmers are offered irrigation for a full season (e.g., *aus*, *aman* & *boro*) at a fixed price payable anytime within the season. The rates are settled through negotiation with the farmers in between BDT 1,250-1,500 per bigha (0.33 acre) for *aus* or *aman* and BDT 2,500-3,000 per bigha (0.33 acre) for *boro* season. *Boro* being the winter season, it requires comparatively more irrigation than the other solutions. Farmers can also pay the amount in installments agreed by the service provider.

Farmers/ Users claimed that, previously they had to pay roughly BDT 4,000 to the diesel pump owner for irrigation in *boro* season and the payment was usually in advance cash. Now a 15Kw SIP can cover 70-80 bigha of land for irrigation. Considering the average values, the system can have an income of BDT 415,000 per year. Deploying a 15Kw SIP needs a capital investment of BDT 4,000,000 approximately. This system occupies around 14-15 decimal of land for which the lease value is approximately BDT 5,000 per year. SIP is a very low maintenance system and rarely requires any incidental cost. However, from field data it has been found that to oversee the operations only one supervisor (technician) is deployed for eight SIP in a close proximity for which the implementer uses to pay BDT 8,000 per month. Accumulating the above facts, yearly operations and maintenance costs result to around BDT 17,000 (Detail Financial analysis is given in the annex).

Apart from the pure financial aspects, other economic benefits that SIP has over conventional diesel pump includes reduced carbon footprint, less pollution resulting long term health benefits, less subsidy on diesel (by GoB), sustainable solution, etc.

In the table below CPL has assessed financial feasibility of SIP against SAT framework prescribed criteria.

Table 4.3.3.3: Technology Feasibility against Financial Criteria

Financial Criteria	Facts/Findings	Performance (Low to high)	Score (1 to 10)
FC1. Capital investment	Investment requirement is low	High	7
FC2. Operation and maintenance costs	Operations and maintenance costs are low as no raw material is needed to be fed into	High	8
FC3. Benefits (energy, flexible payment, uninterrupted service, enhanced biodiversity)	Energy output and energy efficiency is quite high; users can control the water flow as per requirements in a cheaper rate	High	8
FC4. Economic viability	High NPV, High IRR, small payback period	High	7

SIP is a significantly cheaper and cleaner alternative than diesel powered systems. It needs a comparatively high capital investment. Operations and maintenance costs are quite low as no raw material need to be fed into; it rarely requires any incidental cost.

As the economic benefits justify the 50% grant/subsidy model of IDCOL model, the IRR has been calculated based on the subsidy model. The cost of equity has been considered to be same as usual bank rate i.e. 14%. Based on the aforementioned assumptions, the project IRR is 14.7 whereas equity IRR is 32.6 for a 15Kw SIP. Positive IRR was calculated in a subsidized model; payback period was calculated as 6 years for IDCOL model.

By reducing irrigation costs, solar pumps have becoming popular, especially in areas without electricity grid coverage. Compared to their diesel counterparts, these pumps are also more reliable and easier to maintain. As per the present context, replacing all the electric and diesel pumps for irrigation with Solar water pumps can save up to 760 MW of electricity and more than 3200 crore of foreign exchange.

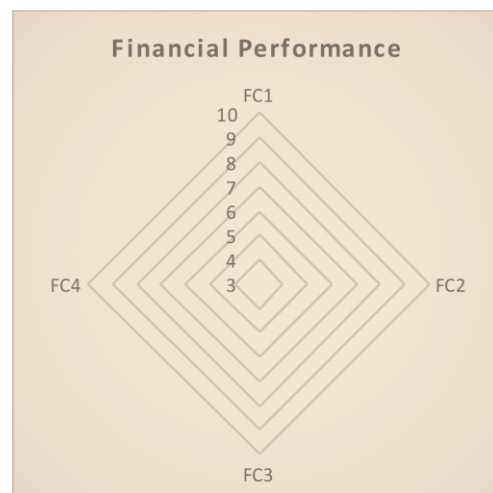


Figure 4.3.3.3: Financial Feasibility of SIP

4.3.3.4 Environmental Feasibility of SIP

SIP can completely substitute the conventional diesel pump and hence can reduce the pollution in a significant amount. Diesel pumps produce polluting particles and generate noise. Burning of one liter of diesel produces roughly 2.4 kg of CO₂⁵ (let alone other diesel exhaust particles (DEP)). The operation of diesel generated pumps is also associated with high health hazards.

In the table below CPL has assessed environmental feasibility of SIP against SAT framework prescribed criteria.

⁵ <http://timeforchange.org/what-is-a-carbon-footprint-definition?page=1>

Table 4.3.3.4: Technology Feasibility against Environmental Criteria

Environmental Criteria	Facts/Findings	Performance (Low to high)	Score (1 to 10)
EC1. Land/ space requirements	Need greater space than other options; still justified	Medium	5
EC2. Affecting biodiversity (ecology; crop, fisheries, etc.)	Fully operated by renewable energy, but no conservation/back up system is integrated	Medium	6
EC3. Raw materials consumption	Low requirement	High	7
EC4. Emissions	No CO ₂ emission	High	8

SIP does not pose any threat or risk to its users or environment. SIP does not produce any emissions or generate no noise. It has low raw material consumption requirement and has shown good resilience against climatic factors. Also this technology uses only solar energy as its power source. However, it has comparatively high space requirement than other similar options. Although it is operated by renewable energy, but no conservation/back up is integrated in the system. The solar irrigation technology makes use of clean, renewable energy possible; provides numerous environmental and financial benefits; and enables sustainable development even in the remotest pastures of Bangladesh.

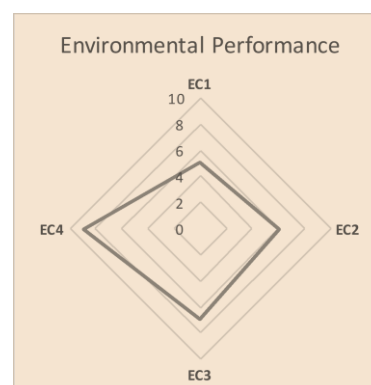


Figure 4.3.3.4: Environmental Feasibility of SIP

4.3.3.5 Over all Feasibility of SIP

Table 4.3.3.5: SWOT analysis of SIP

Strength	Opportunity
1. Good energy efficiency and output performance 2. Management System is compatible; easy to operate and maintain 3. Tested technology; compatible to supply required energy for irrigation; technically durable 4. Environmental hazard free technology; socially acceptable 5. Low cost technology (low investment; low operational costs; reduces fuel cost significantly) 6. Unlike diesel run pumps, it is noise free 7. AC/DC pumping options	1. Can enhance better access to irrigation services 2. High acceptability among community members 3. Construction materials are mostly locally available; LSP (local service provider) model can be promoted
Weaknesses	Threats/ Challenges
1. Requires sustainable fresh water source for the pump (river/ canal/ pond source)	1.No established market actors or distribution system yet

If summarized, SIP is a low-cost solution and has already been tested and piloted in different parts of the country. So it can be a reliable irrigation alternative for polder farmers as it will help to reduce costs and lower diesel dependency. It has good energy efficiency and management is simple.

However, SIP will require fresh water source for pumping and at present there is no ready supply chain.

4.3.4 Target Market for SIP

In polder areas farmers and local service providers (who will sell irrigation services to community farmers) would be the target market for SIP. Currently most of the irrigation in that region are done by diesel powered pumps. Diesel is an expensive fuel and farmers often have to wait in queue for a long time as number of service provider is not sufficient against number of service receivers. Therefore, SIP can be an attractive alternative for both farmers and local service providers.

4.3.5 User and Usage of SIP

This technology has already been tested and piloted in different parts of the country. IDCOL usually approves a SIP project in any location if it meets the following three criteria: a) crops are grown in all three seasons (*aush*, *amon*, *boro*), b) off-grid areas where government will not avail power connection for irrigation services in near future, c) high local demand. IDCOL also check whether there is any river, branch river or canal in nearby to facilitate irrigation. If there is no water source nearby, bigger systems of SIP (9.2Kw and 15Kw) are also not feasible at that very area.

One concern need to be noted that, during monsoon it rains adequately all over the country and the need to irrigation is minimal that time. So at that time SIP does not add good value and remain mostly underutilized.

4.3.6 Business Model Attributes and Requirements for SIP

Table: 4.3.6 Business Model Attributes and Requirements for SIP

Potential Service Areas	- Polder areas where the cost of running traditional water piping or diesel pump is cost prohibitive or farmers are needed to provide water with off-grid solution - Polder areas where farmers often have to wait in queue for a long time for service as number of service provider is not sufficient against number of service receivers
Business model type	- Household or LSP (Local Service Provider) based model - According to the 50% grant/subsidy model of IDCOL, the project IRR is 14.7 whereas equity IRR is 32.6 for a 15Kw SIP
Potential Development Partner(s)	- IDCOL (50% grant, 35% loan at 6% interest, soft term loans) - World bank (channels IDA funds); Climate Change Resilience Funds (BCCRF); the Global Partnership for Output Based Aid (GPOBA); USAID - Local level POs of IDCOL who can take loan from IDCOL - Rural Services Foundation (RSF)
Potential Private Partners	- Rahimafrooz Renewable Energy Ltd. (RREL) - Some local machinery workshops, manufacturers and SMEs have been assembling and marketing their local SIP versions - Available in Alibaba.com and Amazon.com

4.3.7 Inclusive Business Service Options of SIP

According to the field data, SIP offers irrigation facilitating in a cheaper rate than a diesel pump to the farmer. So gradually it will probably be more popular and demandable than the conventional irrigation technologies. Eventually it might seem to be a good option to a farmer/ rural enterprise for considering it as a service modality business. But high subsidy/grant (IDCOL model supports 50%) is mainly triggering the above scenario and the implementing organizations can offer low price for their services.

Farmlands that are not flooded during rainy season – and therefore suitable for 3 crops per year – are ideal for solar pumps, which can provide power for about 20 acres of land and 3 annual crop irrigations. And given Bangladesh's fragmented land ownership, a group of 20-25 farmers can associate to buy water from one irrigation pump. Solar-powered irrigation also reduces government's fuel subsidy for the agriculture sector as well as diesel imports.

4.4 Containerized Solar Power System (CSPS)

This specific technology type was shortlisted in our initial level screening and scoping phase. However, during data collection for detail assessment, we did not find any relevant service provider or market stakeholders of this technology in Bangladesh. Most of the relevant companies and service providers are based in other countries. Therefore, due to different logistical constraints, we mostly had to rely on email conversations, skype calls and documents shared by different companies for relevant data.

Some containerized power systems, their applications and feasibility analysis (technical, social, financial and environmental feasibility) are given below.

4.4.1 Brief Description about Major Containerized based Solutions

4.4.1.1 Solar Containerized blast freeze system by TNO Netherlands



Figure 4.4.1.1: A typical Containerized System by TNO Netherlands

TNO a reputed Dutch company and partners has designed a standalone blast freeze system fully driven by solar energy. Blast freezing is a process in which fresh food products are preserved by subjecting them to very low temperatures (-40 degrees C) for about one 1 minute. This ensures the food is still fresh when unfrozen to be used by consumers, therefore maintaining the value of fresh food. The designed system can perform this on location at the farm on solar power. Within the polder region there are various farms and fishing ghers that require cold storage systems. The region is also a frequently visited by natural disaster. A standalone cold blast system may be a very good solution for storage problems.

New Blast Freeze Concept

Although a new and emerging technology, standalone solar blast freeze systems are available on the market. A drawback of these systems is that they utilize electrical battery storage to be able to run when there is no sun available. These batteries take up space, limit capacity and are costly due to frequent replacements. TNO and partners have taken a containerized solar power system concept and utilized it as a blast freeze system. They have modified the design by exchanging the battery storage with phase change materials (PCM). The buffer is therefore not electrical energy but cold energy stored in the PCM materials, eliminating a large percentage of batteries required as well as reducing the need for backup generators.

PCM storage design

The PCM system is used to store excess cold energy at very low temperature (-40 degrees C). During the day the blast freeze unit is fully powered by the sun and operated. The cooling engine provides energy for the blast freeze operation as well as excess to charge the PCM materials. At night or during times of low solar availability energy for the blast freeze operation is taken from these PCM buffers. In addition the PCM buffers are used for storing (cooling) the blast freeze product.

System Characteristics

The standard design is based on a single 20 feet container and has a capacity of 1-2 ton of product. The idea is that the system is to be transported to the farm location, where the solar panels are folded out or placed to the sides. The product is harvested and processed directly in the system. More capacity can be added due to the modularity of the containers. An additional storage container can also be added depending on the amount of harvested product. This container can be a completely insulated container for storage only with a small cooling engine/PCM storage buffer to keep the product at -20 degrees C. The current calculated return on investment for a base case in Kenya for fish farming is around 7 years. Within the polder area similar performance can be expected. The system is also capable of providing electricity nearby. This attribute makes it function like a CSPS. However the standalone blast freeze system is not primarily built for electrification support. Batteries here will not have a long life if used in this mode. The good aspect of this technology however is its capability to upgrade. To perform complete CSPS role alongside its freezer role modules can be upgraded.

Applications: Their systems are used in applications such as:

- Rural hospitals and blood banks
- Rural communities and Markets
- Off grid farming and storage Residential, retail and off-grid cell towers for the developing world,
- Self-sustaining energy and clean water to remote, off-grid locations

4.4.1.2 REC SolarBox



Figure 4.4.1.2: REC SolarBox

REC is a Norwegian company founded in 1996. By the end of 2015 the company has produced 20 million panels. REC has had the sustainable production of clean energy products as its core focus, growing from a pioneer in the solar industry, to a world leader. The REC SolarBox solution is an innovative micro solar power station in a container, designed to provide power in remote/rural areas with limited grid access and high diesel prices. Originally designed with disaster relief in mind, the all-in-one, off-grid solution is designed for mobility, rapid deployment and durable operation.

Commercial customers with a need for supplemental, off the grid power supply will appreciate the energy independence and flexibility provided by the REC SolarBox. The hybrid solution uses REC solar panels to produce the bulk of electricity required and includes the option of a diesel generator for backup purposes.

Packed into a standard ISO 20-foot shipping container, it comes in 10-60 kW model sizes, with a battery bank to ensure operation outside sunshine hours.

Each REC SolarBox comes with:

- **REC solar panels:** To produce bulk of electricity.
- **Charge controllers:** Determine energy flows.
- **Battery bank:** Ensures operation outside sunshine hours.
- **Inverter:** Converts DC power into usable AC power.
- **Backup power source:** From either grid connection or an optional diesel generator.

Applications:

- Disaster relief
- Humanitarian efforts
- Support for rural institutions
- Residential, retail and off-grid cell towers for the developing world,
- Self-sustaining energy and clean water to remote, off-grid locations

4.4.1.3 Multicon Energy Power Rack (EPR)



Figure 4.4.1.3: Multicon Energy Power Rack

Multicon is now a German success story in renewable energy. For 10 years, the Multicon Group has been realizing innovative photovoltaic solutions. The central business activities are the development, production and assembly of solar power plants. Multicon has specialized in mobile off-grid solutions since 2010. Power is generated on the road using the newly developed solar container and Trailer. As they can be used anywhere and are free of pollutants and inexpensive, mobile off-grid systems are an economical and quick solution.

The EPR is a mobile 6 kWp photovoltaic system that is installed in a 20-foot half-height container. The system is placed on existing containers and provides energy immediately. Inside the half-height container are high-power modules, inverters, batteries (lithium iron phosphate) and an intelligent energy management system.

The EPR is a plug and play system because everything is pre-installed and wired. With mechanical and hydraulic support, it can be set up by 2 persons within 5 minutes. The EPR is absolutely noiseless and free of harmful substances. At a global irradiation of 1,800 kWh, the system produces 10,000 kWh per year, or 30 kWh per day.

At the same time, the unused energy is used to supply hot water (water tank optional) so that about 500 liters of hot water are available daily.

As the containers are merely placed on other containers, they are particularly suitable for areas of use with limited space requirements.

The EPR can provide sufficient power for local markets hospitals, large construction sites, and refugee camps; it can also be used for water desalination, for example.

As any number of containers can be interconnected, they can also cover a high demand for electricity. They can generate single-phase and three-phase power. Two containers can be easily transported on a two-axle HGV.

Applications:

- Disaster relief
- Humanitarian efforts
- Support for rural institutions
- Residential, retail and off-grid cell towers for the developing world,
- Self-sustaining energy and clean water to remote, off-grid locations

4.4.2 Demand and Supply Situation of CSPS

Currently CSPS has no presence in Bangladesh but the technology is promising and capable. The system is large yet compact and easily deployable. As a result it can be employed near population centers, schools, small hospital and clinics alongside market places within the polder region. CSPS systems are more than capable of providing 24/7 electrification for many rural enterprises and households at a time. This technology would have high demand within localities where there is no REB electrification nor any opportunity to receive electrification support within a short period.

4.4.3 Feasibility Analysis of CSPS

In this section, CPL has analyzed CSPS against different feasibility sub-criteria and scored accordingly. the team tried to determine against which feasibility sub-criteria CSPS performs strongly or poorly. 'low/ medium/ high' scores against different sub-criteria on a basis of a scale of 1-3 were assigned. Different weights were assigned against different criteria. Weights were put as per client priority and renewable energy expert suggestions. Detail calculations and weights are given in the Annex B.

Please note that the feasibility analysis done in the sections below are based on secondary data gathered from different articles, websites and reports, or from telephonic or skype conversations with the vendor.

4.4.3.1 Technical Feasibility of CSPS

Mobile and independent solar containerized systems provide electricity to remote locations. These can offer energy solution to polder areas which are not connected to the grid. The complete system is factory pre-wired and tested to assure safety and reliability.

As we can see in table 4.4.3.1, energy output and efficiency is moderate with some loss due to thick wire and DC-DC converter. It is moderately compatible with existing energy needs and has high ease of operation. However, no marketing channel or after sales service provider (maintenance or repair) exists in local or national market at present in Bangladesh. Besides, this system is huge and in the rural or polder context, mobility of this system from one place another might be a big concern.



Figure 4.4.3.1: Technical Performance of CSPS

Therefore, it scored low on those aspects in the following table. This is also reflected in figure 4.4.3.1.

Table 4.4.3.1: Technology Performance against Technical Criteria:

Technical Criteria	Facts/Findings	Performance (Low to high)	Score (1 to 10)
TC1. Compatibility with existing situation	Fully compatible	High	7
TC2. Output	Moderate output	Medium	5
TC3. Energy Efficiency/ Performance	Moderate efficiency	Medium	5
TC4. Ease of Operation	Easy to operate	High	8
TC5. Extent of local materials/ resources use	Cannot be fabricated by local materials fully foreign design	Low	3
TC6. Ease of Maintenance	Easy maintenance; quite low maintenance system	High	7
TC7. Substitutability	Difficult to substitute	Low	3
TC8. Durability or Longevity	System has several components; as a whole the system durability is medium	Medium	5

4.4.3.2 Social Feasibility of CSPS

As it can be seen in table 4.4.3.2 and in figure 4.4.3.2, the technology has good acceptance in communities and resettlements or rehabilitation issues have been insignificant.

Because electricity generated by CSPS can be used to power various onboard systems and applications, it might improve quality of rural lives significantly. Also, occupational risks and hazards are minimum.

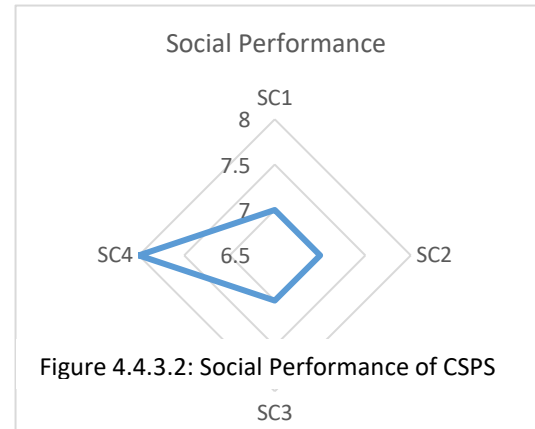


Figure 4.4.3.2: Social Performance of CSPS

Table 4.4.3.2: Technology Performance against Social Criteria

Social Criteria	Facts/Findings	Performance (Low to high)	Score (1 to 10)
SC1. Acceptability within the local culture/ context	Good acceptability as it is a silent, smoke free	Medium	5
SC2. Extent of necessary resettlement and rehabilitation of people	Insignificant	High	8
SC3. Improvement of quality of life	Less pollution and decreased cost create better life	High	8
SC4. Occupational risks and hazards	Safe and hazard free solution	High	7

4.4.3.3 Financial Feasibility of CSPS

CPL managed to get quotations of Ecos PowerCube and Energy Solutions, a British containerized solution. An off grid system in powder coated custom steel enclosure (1513 x 1650 x 1051 mm WxDxH) which includes 117 Kwh (60Kwh useable) of gel 2 volt batteries (48V), 30000 VA inverter/charger, control panel with remote data logging, and generator auto start connection would cost USD 46,750. In Bangladeshi taka that would be around BDT 37,87,000. If we look at the price, it is supposed to be way beyond the average affordability of farmers or inhabitants of polder areas. Only if large financial institute or government provide subsidy then this technology can be installed in polder areas.

The following table and figure (table 4.4.3.3; figure 4.4.3.3) describes financial performance of CSPS against SAT framework prescribed criteria. It can be seen that, capital investment is quite high and therefore, economic viability is also low. Therefore, it received low score on those components.

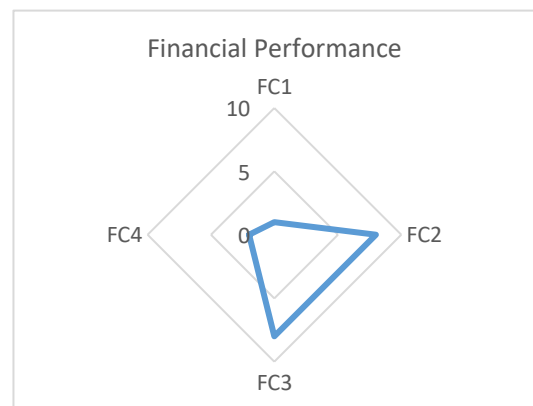


Table 4.4.3.3: Technology Performance against Financial Criteria

Figure 4.4.3.3: Financial Performance of CSPS

Financial Criteria	Facts/Findings	Performance (Low to high)	Score (1 to 10)
FC1. Capital investment	Investment requirement is very high	Low	3
FC2. Operation and maintenance costs	Operations and maintenance costs are low as no raw material is needed to be fed into	High	7
FC3. Benefits (energy, flexible payment, uninterrupted service, enhanced biodiversity)	Energy output and energy efficiency is quite high; users can control the water flow as per requirements in a cheaper rate	High	7
FC4. Economic viability	High NPV, High IRR, small payback period	Low	2

4.4.3.4 Environmental Feasibility of CSPS

Table 4.4.3.4 and Figure 4.4.3.4 describes environmental performance of CSPS against SAT framework prescribed criteria. As we can see, it is an environment friendly technology with low/no emission and raw material consumption. However, it requires comparatively higher space to be installed.

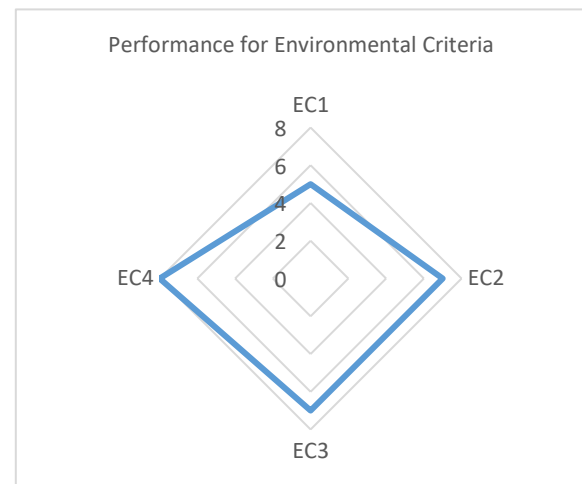


Figure 4.4.3.4: Environmental Performance of CSPS

Table 4.4.3.4: Technology Performance against Environmental Criteria

Environmental Criteria	Facts/Findings	Performance (Low to high)	Score (1 to 10)
EC1. Land/ space requirements	Need greater space than other options	Medium	5
EC2. Affecting biodiversity (ecology; crop, fisheries, etc.)	Fully operated by renewable energy	High	7
EC3. Raw materials consumption	Low requirement	High	7
EC4. Emissions	No CO ₂ emission	High	8

4.4.3.5 Overall Feasibility of CSPS

When summarized, it can be said that CSPS system is an expensive system and currently not in use in Bangladesh. Although the technology has promises but it was not found as a feasible technology for the

polder areas in present situation unless BGP decides to invest heavily on supply chain development and provide large subsidies for purchase. Before deploying a CSPS system within the polder region it must be assured that the location in concern would not receive REB grid electrification in a long period.

Furthermore, CSPS systems require accessibility for the module. The container of the system needs to be transported via large truck to the location. This would be a challenge within the polder region as some locations where CSPS would be beneficial may not have good road network.

This ability to relocate however makes CSPS a very useful system to operate. With proper support, it can be transported from location to location during natural disaster or priority need basis. This does open a business modality but due to the high price of CSPS this would not be cost beneficial.

Table 4.4.3.5: SWOT analysis of CSPS

Strength	Opportunity
1. Good energy efficiency and output performance 2. Management System is compatible; easy to operate and maintain 3. Environmental hazard free technology; socially acceptable 4. Multiple role capability 5. Easy to operate and mobile	1. Can enhance services within a community 2. High acceptability among community members
Weaknesses	Threats/ Challenges
1. Large investment capital required; low economic viability. 2. Difficult to mobilize 3. Not available in local market 4. No after sales service	1.No established market actors or distribution system yet

Chapter Five: Recommendation & Conclusion

For on grid or off grid renewable energy is a very promising technology for the polder regions. For on grid users these technologies provide valuable support during load shedding and natural disasters. These technologies are also affecting daily life as cost reducing mechanism. For off grid users these technologies are the only source of energy. The lives of the off grid people revolve around the benefits of renewable energy. In this section we summarized our findings and provided recommendations for Blue Gold based on our findings.

If we summarize our findings, we can say that **Solar Home System (SHS)** is the most widely used renewable energy technology, used not only within the polder region but all around the country. As this technology is already widespread and a popular rural name, taking this technology to household level in polder area would be comparatively easier and less costly. At present open market actors hold the largest market share of SHS in polder areas. Unfortunately, programs like KaBiKha (Kajer Binimoy Khaddo) and TR (Test Relief) have created a misleading idea among community members that SHS is a relief good and distorted level playing field for open market actors. Another negative aspect is that SHS has limited energy output and efficiency and is restricted to limited usage. Therefore, enterprise benefits are also low.

Solar Irrigation Pump (SIP) can be a very effective irrigation solution for the farmers of the polder region. It is a low-cost solution and has already been tested and piloted in different parts of the country. This technology can help farmers to reduce irrigation costs and lower diesel dependency. It has good energy efficiency and management is simple. However, SIP will require fresh water source for pumping and at present there is no ready supply chain. Although the technology is quite simple and straightforward, no viable market channel has been established yet.

We did not find **Containerized Solar Power System (CSPS)** as a feasible technology for polder areas because of the large investment required to avail it. The cost benefit analysis of this technology is not in favor. Furthermore, the technology is not present in Bangladesh let alone the polder region. Assuring maintenance and other services would be a very difficult work. Especially within the polder region the transportation of this large mobile unit would be difficult. However, usage interventions government or development actors to provide electrification through this system is highly possible. The system is mobile therefore can be shifted from one location to other on need basis. Making the technology suited for relief support.

This leaves us to **Solar Nano Grid (SNG)**. According to our analysis we found that Solar Nano Grid (SNG) as the most feasible technology among four. This is because of the following attributes:

- **Multiple applications and usage:** SNG is primarily directed towards electrification. But the great advantage of SNGs over other technologies is that they do not solely focus on individual households, but also bring additional collective community benefits. The system is flexible enough to support different kinds of household and business activities in a community. An example within the polder region would be irrigation. SNG could provide electrification to electric water pumps which would irrigate the field. SNGs can improve quality of life, empower women, improve health, increase children's educational attainment, and boost the local economy. Besides, Nano-Grid's electricity can also about 50% cheaper than diesel fuel, which is what many people use in Bangladesh.

- **Business Feasibility:** SNG is a business oriented technology. Capable businessmen, entrepreneurs and SMEs in the polders can set up SNG systems and can sell electrification service to clusters comprising households, farmers, shops and SMEs at markets. The payment method for the consumer can be 'pay per unit energy' or 'use as you pay' modality which gives users different payment options. The business would also create job opportunities in community level. And if the electrification demand from an SNG system increases, the system can be upgraded to accommodate more capabilities. This modular upgrading capability allows the system to be always capable of supporting business as per demand.
- **Marketability:** SNG systems are already present within Bangladesh and in successful use. Within the polder region the technology would not have any difficulty to enter. The local open market and NGOs would be easily capable of making the supply chain work and provide enough service support to keep the systems in operation.

Recommendations

To accommodate SNG projects within polder region CPL has identified some recommendations for Blue Gold. They are given below:

Recommendations	Probable Benefits
Greater understanding and cooperation with REB	The principal player within the polder region for electrification is REB. The goal of the Government of Bangladesh to provide complete electrification within 2021. But our study has found out that most places within the polder region would come under electrification within 2018. This creates a situation in which major investment in renewable energy becomes doubtful within the polder region. As such collaboration would help identify the regions within the polders where electrification would not reach due to geographic or logistical region. These places would be ideal for future SNG projects. Furthermore REB has a plan to introduce renewable energy solutions for remote locations. A partnership opportunity may develop if Blue Gold manages to become part of the 100% electrification goal through SNG projects in partnership with REB.
Develop relationship with potential development partners for renewable energy project	In order to implement a SNG project, Blue Gold should develop business to business relationship with other players of this technology within Bangladesh. This is a vital area for development because Blue Gold lacks the technical knowledge and connections to ensure an effective operations system. Partnerships such as these would ensure efficient and smooth supply chain that provide support for manpower development, ensuring high product quality etc.

Develop awareness of benefits within polder region of renewable energy	Renewable energy has benefits on different criteria. These benefits and advantages are required to be understood by local population within the polder to fully utilize the projects potential. Only through a detailed promotional campaign the people within the polder region can be put on board with the renewable energy project.
Create polder wise partner inclusion guidelines and process within SNG projects	To be successful within the polder region, many local players along with private organizations have to be included in the process. These players could be shop owners or land owners or farmers or local associations. The inclusion of local polder wise partners ensures security of the project and increases its success probability.

Apart from laying the ground work for SNG based projects, Blue Gold should also look to new technologies for new possibilities. For example, the Dutch technology of standalone blast freeze system based on CSPS (by TNO) could be potential technology with which BG can work with. Within the polder region, many farms, fishing ghers, markets require cold storages to safely store their produce and maintain quality. Hospitals within the region would benefit greatly by receiving assured freezer support. Based on CSPS, this technology can play dual role and provide electrification support as well. With collaboration with Bangladesh government and private organization, alongside involvement of local players, standalone blast freeze system should have high success rate and would improve the lives of the people around it greatly.