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Renewable Energy Context, Scope, Application and Green Business in Bangladesh

By Professor Dr. Kazi Abdur Rouf
Noble International University, Canada

Abstract- Energy is inevitable for development and its demand is increasing day by day. Energy is essential and important for human life. However, energy from fossil fuel (coals, diesel, kerosene, wood etc.) generates carbon, carbon dioxide emissions, green house emissions that pollute air, and destroy environment resulted global warming that's harmful to living beings and nature. Hence energy scientists are looking for alternative energy resources uses that are environmentally friendly and good for human being. They are provoking for renewable energy (solar radiation energy, bio gas energy, wind energy, water wave energy, CNG energy and hydropower energy) use because PV technologies produce very small amount of CO2 compared to the emissions from conventional existing fossil fuel energy technologies. Therefore, renewable energy (RE) uses is less harmful to living beings and environment (air, water and land). This paper talks about fossil fuel energy and renewable energy use and their consequence and impact respectively in the nature and society.

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Renewable Energy Context, Scope, Application and Green Business in Bangladesh

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The paper identifies different RE resources and different RE projects undertaken in the world particularly Bangladesh. The study explores RE resource utilization different business models, programs, and their benefits in Bangladesh. The study finds Bangladesh has developed a Government managed private apex organization named IDCOL (Infrastructure Development Company), which is involved in coordinating, counselling and financing to the RE implementing agencies in Bangladesh. The study discovers Grameen Shakti, a sister organization of Grameen Bank, is the largest RE implementing organization not only in Bangladesh, but also in the world. GS has developed a micro-utility RE financial model that has disseminated to the IDCOL partnered RE implementing agencies in Bangladesh. The RE implementing agencies apply the GS micro-utility financial model in their own programs in Bangladesh. However, RE resources like solar panels, biogas plants, wind pumps etc. are expensive for the low income people. The RE technologies need further improvement for to not only more handy at the micro level, but also valuable at the economic scale.

Keyterms: Bio gas, climate change, fossil fuel energy, grameen shakti, green house gas emission, global warming, renewable energy and solar panel.

Author: Professor of Noble International University, USA, and Senior Research Fellow,Faculty of Environmental Studies, York University, Canada. e-mail: kazirouf@gmail.com

I. Introduction

It has been alarming the global warming is increasing because of fossil fuel CO_2 emission and other greenhouse gases consequences climate change. Now carbon emission, green house emissions are serious issues for environment pollution and climate change that have been forefront to the global community. Today's development in the advanced countries has resulted in global climate change and massive environmental damage. Many programs have already been initiated throughout the world in order to reduce GHG emission, which enhances mainly the utilization of renewable energy technologies. It is evident that the protection of climate and environment is only possible through complete reliance on renewable energy technologies. Environment and climate issues thus, have been significant considerations before many of the countries (EU countries, Japan) for the application of PV systems. So, large PV applications will have to be seen from the perspective of clean energy development and environmental protection. Bangladeshi people especially rural people and many industries are suffering from electrical power and energy. However, Bangladesh has huge renewable energy (Solar, biogas, and wind pump etc.) potentials because of its geophysical condition. Rural people of Bangladesh depend on biomass, crop residues, plant debris, animal dung and wood for fuel creating deforestation, flood, soil erosion and health hazards etc. to living beings. Women and children, on whom the burden of collecting fuel falls, suffer the most. They are the worst victims of indoor air pollution such as smokes in the kitchens. The combustion of non-renewable fossil fuels like petroleum, natural gas and coal produce the greenhouse gases up to the level which causes the rapid rise of global temperature. Research shows the renewable energy sources release very negligible amount of CO_2 to the atmosphere.

Many NGOs, private agencies and public institutions are involved in renewable energy green businesses and earn income by selling renewable energy products to people in Bangladesh. The paper studies the context of renewable energy in Bangladesh, its scope and applications there. The research also discerns renewable energy business models that exit in Bangladesh. In the paper, the author incorporates his working experience with Grameen Shakti (GS) and the

collected data from different RE implementing organizations in Bangladesh during his visit to Bangladesh in September 2014-April 2015.

II. Environmental Issue

Green house gases (CO_2 Ch_4, and N_2O) emitted in burning of different types of fuel lead to air pollution, environmental pollution and global warming. GHG emissions factors are mostly due to CO_2 are shown below.

Table 1 : GHG emission factor

Item	GHG emission factor
Kerosene	2.5 ton CO_2/ton
Wood/straw	1.7 ton CO_2/ton
Diesel genset	1.3 ton CO_2 /MWh
Diesel	0.897 ton CO_2/MWh
Bangladesh grid (natural gas 90%)	0.452 ton CO_2/MWh
Natural gas	0.452 ton CO_2/MWh
Hydro, Solar, Wind	0

Source: SWERA, 2007

The gradual increase of global temperature and its consequences affect Bangladesh, risen the sea level of Bay of Bengal. It is because of climate change and because of radiant energy leaving the planet is naturally retained in the atmosphere. The concentration of the atmospheric gases slowly increases and helps to rise temperature. This issue is being termed as global warming, which accelerates the earth's climate change. The earth's average surface temperature, which has been relatively stable for more than, 1,000 years, has risen by about 0.5 degrees Celsius in the past 100 years. The nine warmest years in the 20th century have occurred since 1980 and 1990s were probably the warmest decade of the second millennium (IPCC, 2001). Carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) are naturally formed trace gases produced by the burning of fossil fuels, released by living and dead biomass, and resulting from various metabolic processes of microorganisms in the soil, wetlands and oceans. Along with these gases, chlorofluocarbons, bromofluocarbons including their hydrogenated forms (CFC, BFC, HCFC, and HBFC) have potential to accumulate heat from solar radiation, which are reflected from the earth's crust at longer wave length (Ahmed, 2005). The gas wave lengths are increasing due to both human and natural reasons, and contributing to global warming.

The anthropogenic activities include mainly the production and consumption of fossil fuels, as well as the intensification of agricultural activity changes in land use and land cover. Energy production and use, the largest sole source of CO_2 emissions and a large contributor of CH_4 and N_2O emissions, accounted for 81.7 percent of emissions in industrialized countries in 1998 (UNFCCC, 2000). Another estimate shows that the earth's atmosphere receives around 27,000 million tons of CO_2 in the recent years. As a country the USA is the largest CO_2 emitter in the world, which releases 5,729 million tons of CO_2 every year with 19.7 million tons of per capita emission, and the nearest contributor is China which releases 3,719 million tons with 2.9 million tons of per capita emission. Carbon dioxide, the greenhouse gas largely blamed for global warming, has already reached a record-high level in the atmosphere (Hanley, 2004). It has increased by 30% in the last 200 years as a result of industrial emissions, automobiles, and rapid forecast burning, especially in the tropics. Much of these have taken place since 1960. From 1973 to 2006, the emission of CO_2 has increased at a rate of 79.05%. Other pollutants (e.g. SO_2) are also released at high level from the combustion of coal.

III. World Energy Situation

Among the renewable sources, large hydropower all over the world plays an important role (approximately 80%) among renewable, and contributes around 20% of the total energy generation. But the use of hydropower is no longer increasing due to environmental limits throughout the world (Sorensen, 2005; European Commission, 1997). Hydropower is the largest (17%) renewable resource used for electricity generation. More than 150 countries are producing hydroelectricity by constructing dams. Nepal, India and China have a huge potential in hydropower generation. Among them, Nepal and India have economically exploitable hydropower potential of 84,000 MW and 34,000 MW respectively (Arya, 2001; Khera and Singh, 2001). Moreover, China has already installed a massive hydroelectric project known as Three Gorges Dam with an installed capacity of 18,000 MW and also plans to install larger plants in the near future (Kabir and Endlicher, 2012).

Many developed countries including some developing countries are adopting large scale investment in RETs since the global reserve of non-renewable sources like petroleum, gas, coal etc. gets reduced. Global renewable energy (wind power, solar hot water, geothermal heating, and off-grid solar PV capacity) increased at a rate of 15-30 percent annually during the period 2002-2006. Mass production of electricity using RE has recently been familiar throughout the world. UN predicts that 50% of the world's population now live in cities and this figure will be 60% in 2030. Over 75% of energy consumption is directly related to cities and per capita energy consumption is increasing fast in many cities especially in the developing countries (The world Watch Institute, 2007). The fasted growing energy technology in the world is grid-connected solar PV (growing capacity by 60% per year from 2000-2004), to cover more than 400,000 rooftops in Japan, Germany, and the United States. The average annual growth of PV market over the last 15 years is 30 percent. Table-2 shows World

Energy generation, supply, consumption and CO_2 increasing trend from 1973 to 2006.

Table 2 : Comparison of World Energy related Data (1973 and 2006)

Category	Year 1973	Year 2006	Growth % 1973-2006
Primary energy supply	6,115 Mtoe	11, 741 Mtoe	92.00
Final energy consumption	4,672 Mtoe	8,8084 Mtoe	73.03
Electricity generation	6,116 TWh	18,930 TWh	209.52
Electricity consumption	439 Mtoe	1,347 Mtoe	206.83
CO_2 emission	15,640 Mtoe	28,003 Mtoer	79.05

Source: Prepared from International Energy Agency (2008).

Table -3 provides information on fossil fuel emission produced from different fuel sources.

Table 3 : GHG Emission Factor

Fuel mixed grid electricity production contains huge CO_2, CH_4, N_2O emission.

Fuel Type	Fuel Mix	CO_2 emission	CH_4 emission	N_2O emission	Fuel conversion efficiency	GHG emission factor
	%	Kg/GJ	Kg/GJ	Kg/GJ	%	(tco2/MWh)
Small hydro	4.9%	0.0	0.0000	0.0000	100.0%	0.000
Natural gas	90%	56.1	0.0030	0.0010	45.0%	0.452
Diesel (#2 oil)	5.1%	74.1	0.0020	0.0020	30.0%	0.897
Electricity mix	100%		-	-	-	-452

Note: Global warming Potential of GHG
1 ton CH_4= 21 tons CO_2
1 ton N_2O= 310 tons CO_2
The GHG emission from electricity production of 20062 MKwh in 2004 is 9 million tons. The emission is increasing with the years.

Source: RETScreen analysis in SWERA report 2007.

With availability of effective bright roof areas, satisfactory global irradiation and sunshine duration, the environmental concerns are very practical and pragmatic consideration for the installation of the photovoltaic systems. As a result, countries with capacity of technological innovation and strong economy have emphasized on harnessing energy from the renewable resources. The Kyoto Protocol prescribed that countries largely contributing to GHG emission could take part in emission trading, clean development mechanism and joint implementation to reduce their shares of GHG emission. Germany, Japan, Netherland etc. are some of the industrialized countries, which have been shown their obedience to the protocol since it was adopted.

IV. Energy Concern

a) Bangladesh Energy Concerns

Before 2006, only 40% people of the country are connected to grid electricity and the rest depend mostly on biomass energy, kerosene and diesel powered electricity. Remote villagers and coastal energy users are suffering from energy use. Most of the households do not have access to electricity as there is no power distribution network in the coastal areas. Kerosene is the most common fuel used by the households for illumination purposes. Price of kerosene is often subject to fluctuations with price going up in the event of scarcity of supply. The quality of light from kerosene lamps is poor and not adequate enough for all purposes. Besides, it pollutes the household environment through emission of smokes and is also hazardous. The households have to use dry cell for running different appliances like radio, emergency lighting. The price of dry cell is relatively high. This causes extra financial burden to the household budget. Recently there is a scarcity of biomass fuel for cooking in Bangladesh. The scarcity takes serious in the rainy season because biomasses are under water.

Small-scale private generators are in operation in some markets to provide electricity to the shops for limited hours, usually after the evening. The commercial shops in the non-electrified market places use kerosene lamps, candles, etc. which are not found suitable for their activities. The electrified shops face problems of load shedding, irregular supply of electricity and poor service by the utility agencies.

Most of the industrial units and irrigation pumps located in the coastal areas have no access to the grid-based supply of electricity. They are run by diesel. The diesel engines are facing many mechanical problems. The electrified industrial units suffer due to load shedding, non-cooperative attitude of the utility agencies and their poor service quality. Load shedding

and frequent interruption in the supply of electricity affect the industrial units adversely causing a cut in production and revenue.

Although Bangladesh is also not a big contributor to global greenhouse gas emission, the imminent consequences of climate change in the country are likely to be higher due to sea-level rise and frequently occurring catastrophes. Meanwhile the country has experienced massive destruction due to severe cyclones in the south and frequent flood events, which are reported to be the result of global climate change. It is evident (experts' opinions) that due to the accelerated industrial growth of the developed countries, relatively low-lying countries (e.g., Bangladesh, Maldives) are getting more vulnerable to climate change.

b) Dhaka Mega City Energy Problem

The population of Dhaka City was 6.15 million in 1991. The number of inhabitants in the Dhaka Mega City rose to 14 million in 2008 (2015) now it is 17.9 million. Unofficially the number would be higher than formal statistics. With the dramatic growth of the size of the city population, the demand for energy consumption has also been increased manifold. However, the power situation is not satisfactory at all. The whole system of electricity distribution is poorly managed and continues with more than 30 percent system loss mainly through illegal connections (Alam et al. 2004). Power supply is quite inadequate compared to its peak demand in summer. Dhaka Megacity is supplied around 1, 000-1,200 MW, of electricity against the peak demand of nearly 2,000 MW. The country as a whole continues to have 1,500 MW of deficit, while Dhaka City lacks more than 500 MW.

In Dhaka, the total number of households is reported to be 1,796, 950 where 1, 6252,525 of them are identified as urban and the rest 144,425 are rural households (BBS, 2006). Electricity connections in these households are increasing over the decade. In 1991, the electricity connected households were 74% which increased to 88.76% in 2001. More than 10% households of Dhaka are still without electricity connection. The electricity demand of Dhaka Megacity is increasing at an alarming rate every year due to the rapid growth of population along with the growth of electricity connectivity. Currently the demand is around 1,500-2,000 MW, but DESA can supply a maximum of 1,000-1,200 Mw, which is not satisfactory to the existing demand. As a result the city experiences huge load shedding. The good news is the present government take huge steps to install nuclear plants for electricity generation and made agreement with India for quick rental electricity supply. Although the city has 0.8 million domestic gas connections, many of the households are still without gas connections including slums. Recently compressed natural gas (CNG) has drastically changed people`s transportation system and mobility in the city. Now all vehicles use CNG as their fuel. City dwellers are buying cars that contribute to air pollution in Dhaka city (Hosssain and Badr, 2005).

Nearly 40% of the population of Dhaka Megacity is the slum-dwellers. In 2005, the slum clusters identified in Dhaka Megacity was 4,966, which shared 3.4 million people out of city's nearly 9.1 million (CUS et.al. 2005). Slum population rises to 5.2 million out of total 14 million in 2009. Within the DCC wards (134.282 KM^2), their informal settlements have occupied nearly 10km^2. Nearly 96% of these slum communities are provided with grid electricity with obvious poor connection facilities. The entire households of the slum settlements 3-5 MW electricity can be generated from the off-grid SPV systems. Electricity crisis can immediately solve by nuclear power plant. But the problem would be with the disposal of highly radioactive wastes, although nuclear power would be increasingly important source of the world`s electricity mix (Doman, 2004).

V. Why Need Renewable Energy

Reduction of global greenhouse gas emission to seize global warming requires minimizing the use of fossil fuels. To achieve this, a large scale use of renewable energies must be made over the globe for production of electrical and thermal energy. World resources of oil, gas, and coal are limited and there is a global concern about this but, for Bangladesh the situation appears to be extremely unhappy as per capita reserve of fossil fuels is only 1/50th to 12/100th of world per capita.

According to a recent study by the World Health Organization, around 46,000 people die every year in Bangladesh from exposure to indoor air pollution caused by inefficient traditional cook stoves, with 70% of the victims being children under age of five years. Around 90% of the households in Bangladesh uses biomass fuels and low efficiency stoves for cooking resulting incomplete combustion and corresponding Indoor Air Pollution (IAP) through emissions of greenhouse pollutants and particular materials. It causes severely adverse health impacts which are particularly acute for women and children who are the most exposed groups to indoor air pollution.

The rapid growth of population, industrialization, urbanization and standard living of people demanded for energy and electricity lights. The production and consumption of global energy are still dominated by the non-renewable energies (petroleum, natural gas and coal). These non-renewable energies are mostly used for electricity generation. In 2005, electricity generation worldwide was 17,450 TWh, out of which 40% was generated from coal, 20% from gas, 16% from nuclear, 16% hydro, 7% from oil and only 2% from renewable sources such as geothermal, solar, wind and waste

(Evans et al. 2008). The total electricity generation in 2006 was 18, 930 TWh in which the contribution of coal, gas, oil, nuclear, hydro and renewable was 41%, 20.1%, 5.8, 14.8%, 16% and 2.3 respectively. In 1973, oil (24.7%) and coal (38.3%) made the major contribution in electricity generation. The generation and consumption of electricity have both increased at a rate of more than 200% during 1973-2006 (International Energy Agency, 2008). Fadai (2007) reported that the exploitation of exhaustible non-renewable energy sources results in environmental deterioration, and the renewable energy sources are likely to serve the globe with negligible environmental threats compare to fossil and nuclear fuels.

CO_2 Emissions in Bangladesh

SWERA (2007) finds GHG (Green House Gas) emission from electricity grid (20,062 MKWh) is 9 million tons. By 2020 electricity demand should be doubled and CO_2 emission would be around 18 million tons.

The Table 4 : shows (IEA, 2003) CO_2 emission energy production in Bangladesh

Description	Quantity of emission
Energy-related Carbon Dioxide Emissions	32.9 million tons
Per capita energy consumption	4.0 million Btu
Per capita carbon dioxide emissions	0.23 tons

At least 89% of air emissions associated with electricity generation could be prevented if electricity from photovoltaic displaces electricity from the grid. Fthenakis et al. 2008 and Scheer, 2002 reported that the impending damage to the earth by fossil fuels can only be protected with a solar-based economy. Renewable energy emission of CO_2 is very low. Technologies on wind power generation have been reported as the lowest CO_2 emitter. Hydro and solar PV systems also have low emissions, with average reported values at less than 100g/kWh CO_2 (Evans et al. 2008).

a) Large Electricity Deficit in Bangladesh

The country had an initial installed capacity of 5,202 MW (current rerated capacity- 4,000 MW mainly due to ageing of infrastructures), while average electricity generation at present is around 3,700-3,800 MW against the present demand of over 5,000 MW (BPDB, 2009; World Bank and GTZ, 2009). Alongside; however, the country's electricity demand is increasing over 500MW each year (Stromsta, 2009).

Therefore, Bangladesh has been suffering from energy crisis. Huge load shading, lack of sufficient energy for agricultural irrigation is because of energy crisis. Heavy industries in Bangladesh cannot be developed because of energy crisis. Before 2000s, rural people use biomass fuel for cooking. 50% energy obtained from biomass energy in the rural areas. Indigenous gas (available within the field), oil (petroleum and coal (few from Bangladeshi coal mines and imported) are the major source of primary commercial energy in Bangladesh. Hydroelectric energy sources are managing by the public sector which is very limited and inefficient. The country's power is being mostly generated with conventional fuel (82% indigenous natural gas, 9% imported oil, 5% coal) and renewable sources (4% hydropower and solar). According to Bangladesh Bureau of Statistics (BBS, 2006), around 32% people of the country had electricity connection, and around 4% have natural gas supply. Currently around 40% people are connected with electricity grid. But still 60% people throughout country are still remaining without electricity (Kabir & Endlicher, 2012). However, the annual GDP growth of electricity is gradually rising (BBS, 2006). The electricity connection statistics show more disparity between urban and rural areas. In the urban areas, 70.32% households are connected with electricity, while only 29.68% of the rural households are having electricity connection (BBS, 2006).

The emission of carbon-dioxide in Bangladesh in 2004 was 37.17 million tons and the per capita emission was 0.25 tons. Nevertheless, traditional use of biomass, such as, burning wood, agricultural residues, dung, and livestock along with industrial emission, automobiles are the sources of GHG emission in the country. These gases cause indoor air pollution and health hazards to the people (Uddin et al. 2006). In the energy sector, the two largest greenhouse gas emitters are electricity generation and non-energy use (Urea fertilizer production). These sectors emit approximately 50% of the country's total GHG emission (Alam et al. ND.)

Bangladesh is one of the most disaster prone countries in the world, and is vulnerable to various devastating disasters like cyclone, tidal surge, sea level rise etc. The imminent consequences of global warming due to increase of GHG emissions will certainly affect the deltaic Bangladesh. The country has experienced with massive coastal cyclones and saline intrusion. It is predicted that in the near future, more severe impacts are likely to happen if immediate measures are not undertaken. This tremendous power shortfall and air pollution drives for alternative energy (solar home systems) exploitations in Bangladesh. Solar home systems (SHSs) has covered more than 2.2 million households providing at least some lighting (February, IDCOL, 2015).

b) Greenhouse Gas Emission Reduction in Dhaka

Dhaka is one of the most polluted cities in the world. The concentration of CO_2, other oxides of carbon, nitrogen, sulphur and other pollutants have already crossed the danger level in the sky of Dhaka Megacity.

Emission from industries, brick kilns and automobiles are the major sources of the city's pollutions. In Dhaka, there are around 5,000 slum and squatter clusters where more than 3.5 million people live (CUS et al. 2006). In most cases, the slum dwellers burn crop residues, wood, furnace oil, kerosene for cooking and domestic power, which cause massive indoor air pollution and poisonous gases including CO_2. In order to reduce the emission from the automobiles, the two-stroke engine autos have already been banned from the city, but practically this is not enough to make the situation sustainable. Most of the non-renewable sources (petroleum, natural gas, coal) emit large extent of greenhouse gases. The renewable sources like solar PV system, wind turbines release very low greenhouse gases, which can play a significant role in improving the atmospheric condition of the Megacity of Dhaka. In order to reduce the greenhouse gases to global warming, there is an urgent need of the RETs utilization in Dhaka Megacity.

Table 5 : Fossil Fuel Reserves

Country/World	Gas Trillion cft	Oil million barrels	Coal million tons
Bangladesh	20	5.5	2295
World	5016	1,30, 444	10,967,373

One million ton of coal is to be extracted per year from Barapukuria coal mine in Bangladesh. This is equivalent to 0.03 tcft gas and should provide 240 MW generations by 2007. The following table 6 shows the coal deposits discovered so far in Bangladesh.

c) Conventional Energy Supply and Resources

Energy consumption per capita in Bangladesh is extremely low compare to neighbouring countries as shown in Table below Table 6

Table 6 : Per capita energy consumption (kgoe, 2003)

Country/Region	Energy Consumption	Country/Region	Energy Consumption
Bangladesh	157	India	520
Nepal	355	China	1094
Sri Lanka	422	World	1688
Pakistan	467	OECD	4588

Source: IEA (2008)

The consumption per capita is half of even Nepal and 1/10th of the world. A much higher consumption must be made to raise GDP and to alleviate poverty in Bangladesh.

India has already achieved a remarkable progress in generating power from different renewable energy sources especially solar PV systems, and a substantial amount to budget is allocated in this sector on regular basis to promote the RETs (Islam et al. 2006). The country has an annual capacity of electricity generations of 140 GW, in which 32.1% can be generated from renewable sources including large hydro-projects and the rest can be produced from non-renewable sources (REN21, 2007). The Government of India has recently decided to electrify 67 million remote rural households with solar home systems, where kerosene is used as the major source of energy (Chaurey and Kandpal, 2009). By the year 2020, India has a target of achieving 20 GW of PV generated power.

VI. Energy Status in Bangladesh

About 90% of the population in vast rural areas were practically without electricity. For the benefit of this vast rural people, REB (Rural Electrification Board) was established in 1977. It provides electricity to consumers in a selected area by forming a Rural Electric Co-operative called Pally Bidyut Samity (PBS). Activities of rural electrification co-operative are given below

Table 7 : PBS (Palli Bidyut Samity ctivities in Bangladesh

Description	Achievement
Area coverage/PBS	2000 sq. Kms
No. Of PBS	67
Number of villages energized	41,125
Number of 33/11 KV sub-station constructed	328
Length of power distribution lines	1,73, 125 Km
Number of population in programme area Category wise connection	9,25,13,296
Domestic	45,42,099
Commercial	6,06,666
Irrigation	1,38,869
Industry	95, 0559

Others	12,043
Total	53,94,736

Source: SWERA, 2007.

Table 7 : Production and consumption of Natural Gas in Bangladesh

Category	2000-01	2001-02	2002-03	2003-04	2004-05
Gas Production Gas (109cft	372.16	391.53	421.16	454.59	486.75
Consumption (109cft)					
Electricity	175.27	190.03	190.54	199.40	211.02
Captive	0	0	0	32.03	37.87
Fertilizer	88.43	78.78	95.89	92.80	93.97
Industrial	47.99	53.56	63.76	46.49	51.68
Tea-garden	0.65	0.72	0.74	0.82	0.80
Brick field	0.44	0.53	0.52	0.12	0
Commercial	4.06	4.25	4.56	4.83	4.85
Domestic	31.85	36.74	44.80	49.22	52.49
CNG	0	0	0.23	1.94	3.62
Total Consumption	348.69	364.61	401.04	427.65	456.30

Source: BBS (2006)

a) Imported Fossil Fuels

Bangladesh transport system depends almost totally on imported liquid fuels, but good news is after 2008, CNG fuel is using from national source. Kerosene is used widely for lighting in villages while diesel generators are getting unavoidable. The amount of crude oil and petroleum products imported is shown above in Table 7.

Table 8 : Import of Petroleum Products and Crude Oil

Year	Crude Oil		Petroleum Products	
	Qty (Thousands Tons)	Value (Million US$)	Qty (Thousands tons)	Value (Million US$
2001-02	1225	220	2072	2536
2002-03	1331	289	2214	3319
2003-04	1252	314	2262	4015
2004-05	1063	364	2692	7214

Source: British Petroleum, (2005)

The Table 8 shows cost imported petroleum products is huge in Bangladesh. The good news is now Bangladesh is using less polluting local CNG fuel in vehicles and it is popular there. However, natural gas reserves in Bangladesh are likely to be depleted before 2020 and electricity production from gas may stop. Therefore, more energy supplies using RETs must be developed and utilized.

b) Electrical Energy

During financial year 2005-06, per capita consumption was 136kWh whereas per capita electricity generation was reported to be 167kWh (SEWERA, RERC, 2007). At present, the electricity supply situation little better than previous. The Government installed several nuclear plants for generating electricity power. However, during peak season (agricultural irrigation season) 5 am-10 pm 600 Mw of load shedding is required (CES, 2006). The World Bank (2007) estimates an annual loss of nearly 1 billion dollars in Bangladesh due to its unreliable power. Stromsta (2009) reported that the power demanded in Bangladesh is increasing at the rate of 500 MW per year. The maximum electricity generation was 4,130 MW in 2007 and 4,036.7 MW in 2008.

The availability of the most useful form of energy, electricity, is again extremely small as shown below Table 9.

Table 9 : Electricity Generation and Consumption in Bangladesh, 2005-2006.

Item	Quantity
Installation Capacity	5,275MW
Average demand	4,300-4,500MW
Average generation	3,200-3,300MW
Per capita generation	167 kWh
Per capita consumption	136 kWh

Figure 1 below presents the fossil fuel supply for electricity generation which shows that natural gas is the major energy source.

Natural gas	89%
Oil	7%
Hydro	4%

Figure 1: Generation pattern FY2004

The shortfall in electricity generation continues till today mainly due to old inefficient generators requiring heavy maintenance.

The table below presents Bangladesh fossil fuel reserves. It is found Bangladesh gas reserve is around 1/250th while coal reserve is 12/5000th of the world reserves (SWERA, 2007). Per capita reserve of gas in Bangladesh is then around 1/5th and of coal 1/100th of world per capita. This situation is enough for Bangladesh. Fossil fuel reserves of Bangladesh are compared with world reserves in the Table 10 below.

Table 10 : Coal deposits discovered in Bangladesh

Coal Fields	Depth of coal seams in meter	Reserves in million tons
Jamalganj, Bogra	640-1158	1053
Barapukurias, Dinajpur	118-506	303
Khalaspir, Rangpur	257-451	147
Dighipara, Dinajpur	250	200
Phulbaria, Dinajpur	152-246	572

Source: Energy & Power, August 1, 2005 and May 1, 2006.

c) Coal

Bangladesh began its first significant coal production in April 2003 with the opening of the Barapukuria Coal Mine in Dinajpur area of north-west Bangladesh with an estimated reserve of about 300 million tons. It is planned that 85% of its annual production of 1 million ton will be utilized to produce electricity; the rest will be used as fuel for brick making and other purposes.

d) Oil

Bangladesh contains small oil reserves of 56.9 million barrels and produces around 7000 barrels per day (bb1/d) of which 6000 bbl/d is crude oil (Power Cell 2006).

Natural Gas: Natural gas is Bangladesh's only sizeable source of commercial energy with total production of 5.5 tcf. Estimates from Petrobangla put net reserves at 15.3 tcf as of mid 2004 (proven reserve is lower) (Power Cell, 2006).

e) Hydro

At present only 230 MW of hydro power is utilized in Kanarfuli Hydro Station, which is the only hydro-electric power plant operated by Bangladesh Power Development Board (BPDB). Apart from Kaptai, two other prospective sites for hydro power generation at Sangu (100 MW) and Matamuhuri (75 MW) river are identified by BPDB (BPDB, 2009).

f) Traditional Biomass Energy

Biomass is the most used energy source in Bangladesh which accounts for 76% of the total final energy consumption in Bangladesh. The main sources of biomass fuels are: Trees (wood fuels, twigs, leaves, and plant residues), agricultural residues (paddy husk, bran, bagasses, jute stick etc.) and livestock (animal dung). The biomass is used for mostly for cooking in rural areas and for rural industries. It forms 68% of total energy supply while 32% is supplied by commercial energy (including hydro power) (Kabir & Endliocherr, 2012). Inefficient cookers employed produce unhealthy oxides and particles from traditional ovens. Presently 12 million tons of coal equivalent biomass is consumed in the industrial and domestic sectors along with commercial energy. Fire wood forms only 10% of the fuel supply that indicates in the Table-11 below.

Table 11: Estimates of Energy Supplied by Traditional Biomass Fuels ('000 tons of coal equivalent)

Fuels	1999-00	2000-01	2001-02	2002-03	2003-04
Cow-dung	2441	2471	2471	2471	2502
Jute stick	922	966	1010	966	922
Rice straw	1375	1429	1409	12418	1218
Rice hulls	2810	2810	2854	2898	2854
Bagasse	314	340	366	366	392
Firewood	1166	1166	1219	1219	1272
Twigs and Leaves	1325	1378	1431	1484	1537
Other wastes	1186	1230	1273	1317	1361
Total	11539	11790	12033	12139	12258

Source: BBS (Bangladesh Bureau of Statistics, 2006)

g) Indigenous Fossil Fuels

According to BBS, 2006 there are 22 gas fields have identified in Bangladesh and total natural gas reserve is 20.5tcft of which 6tcft gas was produced by 2005 and 14.5 tcft gas was left while the annual gas production is around 0.5 tcft in 2005. 46% of natural gas is consumed for electricity generation and fertilizer production uses 21% of the gas while other consume the rest 33% as shown in the Table 11.

VII. Renewable Energy Application in Bangladesh Until 1990s

Solar energy owns a share of more than 99.9% of all the energy converted on earth (Kaltschmitt and Wiese, 2007). The amount of energy sent to the earth from the sun each year is equivalent to almost 15,000 times of the world's commercial energy consumption and more than 100 times the world's proven oil, gas, and coal reserves (Islam, 2005). The continuous supply of the solar energy to the earth's surface is equivalent to a power of about of 100,000 TW (Kuhne and Aulich, 1992). Solar energy is inexhaustible and available throughout the year all over the world.

Despite the availability of enormous potential of renewable energy, there has not been any significant progress in the promotion and development of RETs by public sector and other sectors until 2010 (Kabir, 2011). It is because highly expensive installation devices, high maintenance costs and lack of strong political commitment. Till to date, the large part of the energy demand of the country (Bangladesh) is fulfilled by traditional biomass, which is predominating particularly in the rural areas. Biomass is the source of energy supply to the rural villagers, but it is unhealthy. Hence there is immense potential in solar energy utilization across Bangladesh because Bangladesh is rich is sunshine whole year. Wind and tidal energy generation potentials exist in the coastal areas. Now huge solar home system is installing across Bangladesh rural areas by NGOs, private sector even public sector promote SHS in Bangladesh.

a) Hydropower

Bangladesh is a flat country does not possess extensive potential in hydropower resource except some small hydro-projects. Karnafuli Multipurpose Hydroelectricity Project (KMHEP) is the first renewable energy development project in Bangladesh setup in 1957 (Islam, 2005). It has capacity to produce electricity 230 MW. This project contributes to 5% of the total national electricity generation in 2003 (Hossain and Badr, 2005). Apart from Kaptai dam project, the B Power Development Board (PDB) has identified two other prospective sites for hydropower generation. They are at Sangu (100MW) and Matamuhuri (75 M) rivers.

Non-renewable Energy Sources in Bangladesh.

The major sources of energy of the country are natural gas, coal and a limited hydroelectric capacity. The entire reserves of exploitative indigenous fossil fuels, with the exception of the coal reserve, are located in the eastern part of the country. This results in a gap of commercial energy supply between the east and the west (Hossain and Badr, 2005). This differentiation is because of indigenous gas fields are located in the Eastern part of Bangladesh and imported oil. In 2004, the shares of natural gas, oil, coal and hydroelectricity to total primary energy consumption were 70.8, 25, 24 and 1.8 percent, respectively (British Petroleum, 2005).

The Government of Bangladesh declared new gas connections shall be no more in Bangladesh (Daily Promothom Allo, May 04, 2015), it is because scarcity of gas in Bangladesh. The entire urea fertilizer manufacturing is based on natural gas. Power plants, fertilizer factories, other industries (e.g. brick kilns, tea processing plants, steel mills, and textile factories), commercial organizations e.g. offices and business centres) and the domestic sector are the end users of natural gas in the country. The gas consumption in the year 2004-2005 was 487 bcf, which on a daily basis is 1,334 MMcfd (million cubic feet per day). This indicates that there has been a large increase in gas consumption. Captive power generation and CNG refuelling are the two demand areas that are responsible for the large increase (Kabir & Endlicher, 2012).

Petroleum Oil is one of the most important sources of energy in Bangladesh. The country utilizes mostly imported petroleum from the OPEAC for mainly transportation, some electricity generation and industrial heating. The major coal deposits of the country are located at Jamalgonj in Jaipurhat, Baropukuria and Phulbari in Dinajpur and Khalispur in Rangpur. It is estimated these coal fields could have 2.55 billion tons of reserves in Bangladesh (Energy and Power, 2009).

VIII. Bangladesh Renewable Energy Sources and Technology Practices

Bangladesh though a small country it has numerous potential sources of renewable energy, for instance, biomass, solar energy, hydropower, wind and tidal energy. Rural people uses energy from traditional biomass- cow dung, domestic wastes, jute stick, rice straws, twigs, etc. Hydropower generates around 5% of the total consumption. So solar and wind energy is find a great potential source of energy in Bangladesh.

Table 12 : Renewable Energy Prospects in Bangladesh

RES Type	Capacity (up to December'08)	Theoretical Potential
Wind	1 M	2,000 MW
Hydro	230 MW	672 MW
Solar PV	15 MW approx	50,436 MW
Solar Thermal	3,000 m3	20<>106 m2
Biogas	.3 million m3	3,675 <>106 m3

Source: Based on Alam et al. (2003).

In Bangladesh, although very few biomass gasification plants have been installed, many biogas Projects Undertaken in Bangladesh. For example, over 24,000 biogas plants have been installed all over Bangladesh (Energy & Power, 2007). Biogas plants in the rural areas are run mainly with animal dung and domestic wastes. The urban solid wastes include wastes from households, industries, hospitals are used in biogas production, but urban biogas production is very limited.

a) Solar Energy Technologies

Generation of solar electricity from solar radiation is basically made with solar cell, which is mainly a silicon–made solid device. A solar cell is defined as a device that directly converts sun-light into electrical energy through the process of PV systems. In order to generate electricity from solar radiation, an off-grid stand-alone or island system generally needs several devices, such as, solar panel, battery, inverter, charge-controller and necessary cables and tools. Energy is generated by the solar panels as direct current (DC), and converted to alternating current (AC) by the inverter. The battery is needed for the off-grid PV systems to store power, and the charge controller maintains the battery at the highest possible state of charge (Grameen Shakti, 2015; SWERA, 2010). Solar cells are electrically connected and placed between glass and tedlar plate, and framed by an aluminum frame. Number of solar-modules and other components (batteries, charge regulators, inverters) can form large photovoltaic systems.

Basic considerations of Solar PV Applications

The angle of the sun throughout the year is important for the assessment of solar incoming radiation. Moreover, extreme wind speed, lightening, moisture and dust can harm to the panels. The temperature of a certain place is a very important factor to receive the optimum amount of solar energy. Normally in a geographical area with 25° Celsius temperature, panels produce the maximum level of solar energy. The more and lesser the temperature than 25° Celsius, the less is the generation of electrical power. It is important to assess the temperature throughout the year. The geophysical features of Bangladesh favours installations of solar home systems everywhere in Bangladesh (Alam et al.(2004); Eusuf (2005); SWERA (2010). It is appropriate areas with more than 25° Celsius in most of the time a year, panels can be installed in the wall of the buildings so that enough wind to keep temperature close to 25° Celsius. Solar tracking system can be effectively used between 23° and 550 latitudes of both hemispheres (Kabir & Endlicher, 2012). Moreover site selection is very important for the installation of large-scale solar PV plants. Mounting of panels is essential to capture optimum level of electricity. The locations having more provision of having sun occurrence are likely to be most suitable areas.

b) Solar Energy

Solar PV generated lighting program in Bangladesh primarily includes on rural houses, small businesses, and income generation activities in the remote rural areas which is being implementing by Grameen Shakti, and other NGOs in Bangladesh. Many SPV aimed at providing income generating opportunities through running motors, permitting longer working hours and facilitating longer selling hours by rural traders.

In Bangladesh, the private sector, commercial as well as non-profit organizations have chosen at least an important renewable energy source for the economic realization. In the initial promotion of SPV, Rahimafrooz, a private battery manufacturing company in Bangladesh played an important role despite having it an unprofitable business due to high tariffs and duties. Rahimafrooz continued to emphasize manufacturing solar grade deep cycle batteries to go with the imported systems. Other private companies like Microelectronics, First Bangladesh Technology and Bangladesh Energy Advanced Studies have also looked for a market share.

The government sponsored organization infrastructure Development Company Limited (IDCOL) in Bangladesh has been involved to a large extent in the promotion of SPV systems and has already installed around 450,000 solar home systems all over the country through the partner NGOs (Haque, 2008; IDCOL, 2009). Grameen Shakti and Bangladesh Advancement Committee (BRAC) in Bangladesh initiated its solar program in 1997 to electrify remote locations too in Bangladesh. Many other NGOs have also involved in installing solar PV systems, biogas plants, wind turbines, hot box cookers and PV-diesel hybrid systems (Islam & Islam, 2005).

c) Solar Tracking System

Among the PV systems, solar tracking system is considered as the latest and most advanced system. It is also known as solar tree or solar concentrator. This system produces additional generation of electricity than the roof mounted system allowing for more efficient convertors for electricity generation (Kuhne and Alulich, 1992). With the movement of the sun, the solar concentrator moves to receive the maximum solar radiation. However, this tracking system is very expensive around E25, 000 (twenty five thousand Euros (Kabir & Endlicher, 2012).

d) Roof-top grid connected PV System

A 1.5 kW roof-top grid connected PV system has been developed and installed on the roof of Renewable Energy Research Center (RERC) in Bangladesh with the support of the Ministry of Science and Technology. It has carried out R & D activities on

solar cookers, solar water heaters, solar dryers, SHSs, etc. (IDCOL, 2014; SWERA, 2010).

e) Roof Mounted Solar PV System

Compared to the solar tracking systems, roof-tied PV system is a cheaper option for the households. Grid connected roof-mounted system appears to be very profitable and secured, although the initial investment is high.

f) Building Integrated PV (BIPV) System

Building Integrated PV (BIPV) system is installed on the surface of the buildings combining solar electricity generation with other functions of the building structure (Bakos et al. 2003). Such systems usually consist of the PV module and waterproofing elements, a PV combiner, a grid inverter and an import /export meter. However, the application of PV systems on the urban building in Dhaka is absent.

g) Ground Mounted Solar PV System

Like roof mounted system, ground mounted grid connected PV system also produces satisfactory amount of electricity. However, here needs open space or land. However, this Ground Mounted Solar PV System is not popular in Bangladesh because scarcity land.

h) Stand alone or Island SPV Systems

Stand alone or Island SPV System is known as an autonomous system. This system is very much popular in Bangladesh, India, Sri Lanka, Ethiopia Indonesia and many other Asian and African countries. The capacity of the solar homer system ranges between 300-2,400 watts. Grameen Shakti and few other agencies in Bangladesh have been installing solar home systems in the remote rural areas of Bangladesh since 1997, which are basically stand- alone PV systems.

i) Wind Energy

Wind energy utilization in Bangladesh is still in the early stage. In the coastal areas, there is a very good potential of generating 20,000 MW of electricity (SEWRA/RERC, 2007). Recently in 2008, 50 wind turbines having capacity of 20kWh each has been installed in Kutubdia, a detached off-shore island of Cox's Bazar District with the self-funding of the BPDB (Kabir & Endlicher, 2012; The Daily Ettefaq, 2008). This wind-battery hybrid system has rarely helped in solving the electricity crisis in the island.

j) Tidal Energy

Tidal Energy is a form of hydropower that converts the energy of tides into electricity or other useful forms of power. Tidal power has the potential for future electricity generation although tide energy harnessing in the world is still very negligible. Tidal energy has an efficiency of 80% in converting the potential energy of the water into electricity. In the coastal part of Bangladesh, the normal tidal head rise and fall between 2 m and 8 m (SWERA, 2007). This tidal range can easily be converted into pollution free clean renewable energy by using the simple low-cost technology of a "tidal Wheel" in the sluice gates.

IX. Institutional Arrangement for Renewable Energy (RE) Exploitations in Bangladesh

The government has made its visionary statement to provide electricity to all by the year 2020 (MPERMR, 2008). In order to achieve this target, there are no so many options before the government except electricity generation through solar PV applications, proposed nuclear power plant and coal based power plants. SHSs can rapidly reach to rural areas with less infrastructure cost from the state. Nevertheless for electricity generation, even now, more than 80% indigenous gas is used, while the reserve is rapidly declining due to over exploitation and misuse (IDCOL, 2014; SWERA, 2007). The other uses of indigenous gas include domestic, industrial (e.g., fertilizer production) and transportation. As result the only abundant source of the country's fossil fuel is reducing at a rapid pace. After 2015, the fuel share of gas reduces from 85% to 61% and only 1% by the year 2030 (IDCOL, 2014; Kabir & Endlocher, 2012). It can be disavowed that after natural gas exhaustion, the country has to heavily depend on coal based generations. But the exploitation of coal often creates social and environmental problems. In such s situation, the government can only encourage investment and other supports for solar power exploitation although only solar PV systems cannot solve the power crisis. In order to provide lighting to the inaccessible areas, the government owned company IDCOL has been assigned to develop installations of solar home systems under the Rural Electrification and Renewable Energy Development Project (REREDP). Grameen Bank is working by the support of IDCOL in Bangladesh.

The public agencies like Bangladesh Power Development Board (BPWB) and the Rural Electricity Board (REB) both have been carrying out projects to promote renewable energy activities. Bangladesh Council for Scientific and Industrial Research (BCSIR), Bangladesh Atomic Energy Commission (BAEC), Local Government Engineering Department (LGED) and Infrastructure Development Company Limited (ICOL, a state-owned non-banking financial institution. These organizations are involved in Rural Energy and Renewable Energy Development Programmes (RERED) in Bangladesh.

a) Affords to increase Energy in Bangladesh

Government of Bangladesh has declared its vision to provide electricity for all by the year 2020. To fulfill this target, utilization of renewable energy

technologies could play a vital role for off-grid electrification with minimum fiscal cost. Currently Bangladesh has made an agreement with Russia to build thermonuclear fusion energy plant for generating electricity and installed nuclear reactors plant at Rupur for 1000-2000MW, there could less risks associated with modern nuclear reactor technology. However grid connection all over Bangladesh is very expensive.

X. Scope of Renewable Energy use in Bangladesh

The recent rapid rise in the growth of solar PV and wind based power generation capacity is not only to gradually replace the conventional power supply system but also to meet the obligations of global climate protection. The developing countries (China, India, and Bangladesh) which are still struggling to produce enough power for their growing industrialization as well as other sectors are focusing on power supplement from the alternative sources. Given the rapid decline of conventional fuels, countries round the globe have devised supportive policy strategies in order to enhance RES exploitation. Among the new renewable (solar, wind, modern biomass, geothermal heat etc.), the installed capacity of wind based power generation is dramatically rising in some of the developed (e.g. USA, Germany, Denmark and developing countries (e.g. China, India). However, the installed capacity in solar PV systems (mainly grid connected systems) takes place mostly in the developed countries (e.g. South Asian countries of India and Bangladesh (Kabir & Endlicher, 2012). Until the end of 2008, the global capacity of solar PV systems is just less than 17 GW, while grid connected system accounts for 13 GW and off-grid system is 4 GW. Until now (2010, Germany alone has already achieved an installed capacity of 7 GW, which is more than the existing power demand (5-6 GW) of Bangladesh (Weiss et al. 1998; and Wengenmasyr, 2008). In Bangladesh until 2010, the exploitation of RES mainly apply solar home systems in the rural areas, a few wind based power generation plants and biogas plants.

Bangladesh has an enormous potential in solar energy, and therefore the installations of small and large-scale PV systems can help to reduce its current share of GHG emission. One family using a typical solar home system can save yearly 290 litres of kerosene by using solar lighting technology and can prevent the emission of 0.76 ton CO_2 per year (SWERA , 2007).

a) Energy demand Scenarios in Bangladesh

Two economic growth scenarios (Low Scenario and Reference Scenario) were considered to forecast future energy demands as presented in Tables 13 & 14. Projected demands for commercial energy and electricity up to the year 2020 under both the scenarios are presented in tables below.

Table 13 : Projected demand for energy (commercial and electricity) under Low economic growth Scenario (business as usual)

Year	1990	1995	2000	2005	2010	2015	2020
	Commercial Energy						
Population (million)	107	118	130	141	153	165	177
GNP Growth Rate (%)	4.44	5.25	5.24	5.24	5.24	6.65	6.65
Per Capital (GNP $)	190	214	242	276	3177	366	424
Energy Coefficient	1.62	1.37	1.37	1.37	1.08	1.08	1.08
Energy Growth Rate (%)	7.13	7.19	7.18	7.18	7.18	7.18	7.18
Per capita use (KgOE)	56	68	92	127	157	219	272
Total Energy (MTOE)	6	8	12	18	24	36	48
Total Energy (Pj)	256	342	512	769	1025	1537	2050
Energy Productivity (MJé$éGNP)	12.59	13.54	16.27	19.76	21.13	25.45	27.32
	Electricity						
Status in Energy mix (%)	35	37	39	37	33	33	33
Total GWh	8205	11584	18315	26063	30994	46491	61988
Per Capita kWh	77	98	141	185	203	282	351
Load factor (%)	55	57	57	57	58	59	60
Peak Load (MW)	1703	2320	3668	5220	6100	8995	11794

Source: SWERA, 2007.

Table 14 : Projected demand for energy (commercial & electricity) under reference economic scenario growth

Year	1990	1995	2000	2005	2010	2015	2020
	Commercial Energy						
Population (million)	107	118	130	141	153	165	177
GNP Growth Rate (%)	4.5	5,4	6.4	7.2	7.7	8.2	8.7

Per Capital (GNP $)	190	214	254	318	416	560	774
Energy Coefficient	1.62	1.37	1.37	1.37	1.08	1.08	1.08
Energy Growth Rate (%)	7.34	7.4	8.77	9.86	8.32	8.86	9.40
Per capita use (KgOE)	56	72	94	131	194	269	384
Total Energy (MTOE)	6	8	12	19	31	46	72
Total Energy (Pj)	256	362	531	827	1314	1979	3055
Energy Productivity (MJé$éGNP)	13	14	16	18	20	20	21
	Electricity						
Status in Energy mix (%)	35	37	39	37	33	33	33
Total GWh	8207	12280	18971	28060	59858	46491	92402
Per Capita kWh	77	104	146	185	263	282	523
Load factor (%)	55	57	57	57	58	59	60
Peak Load (MW)	1703	2459	3799	5220	1158100	8995	17580

Source: SWERA, 2007.

Based on this estimation, the currently installed 450,000 solar home systems all over the country can save 130 million litters of kerosene and 342,000 tons of CO_2 annually (IDCOL, 2014). To consider as rural community based market (50 shops and a 10w florescent bulb each) with solar PV system for lighting that replaces diesel generator can mitigate 1.1 tons of CO_2 per year (Ibid, 2014).

The recently approved renewable energy policy sets targets to meet 5% of the total power demand by 2015 and 10% by 2020 (MPEMR, 2008). The Government of Bangladesh has a target of reducing 6.4 million tons of CO_2 emission through the generation of 2,200 Mw of electricity from renewable sources by 2020. SWERA/RERC (2007) calculated CO_2 reduction possibility with the applications of solar systems and wind turbines. Rahman (2009) reported that on an average 1.8 kWp solar PV system can reduce 900 kg of CO2 emission annually. According to this estimation, the applications of SPV systems on the bright rooftops of Dhaka (in the case of 1,000 Mw of electricity generation) will roughly reduce 500 million tons of CO_2 per year. Although the target seems to be ambitious and far-reaching given the country's RET application scenario, it can be treated as the positive indication towards the application of renewable energy technologies.

In Bangladesh, 60% of the total population still depend on biomass based energy. Agricultural residues (rice straws, jute sticks, rice husks etc.), cow dung, twigs etc. have been being used as fuel for cooking by the rural households since time immemorial. But the inefficient use of traditional fuel sources produces immense indoor air pollution causing massive health hazards particularly to women and children. At the same time, there has been a decline in the supply of biomass mainly due to the high population pressure on agricultural production (Grameen Shakti, 2015).

The major attention of the RE technology is still concentrated into the rural areas although the urban areas generate enormous solid wastes which can be used for power generation and to produce compost. By 2010, the renewable energy sources (especially hydropower) contribute only 4% of the total power generation (4,000 MW) (Hussain & Badr, 2005). The installed capacity of solar PV based power generation accounts for only 25 MW (by 2010) and the wind based generation capacity is still very insignificant (4MW) (IDCOL, 2014; SWERA, 2007). However, the geophysical characteristics (Global horizontal irradiation, sun shine duration etc.) of Bangladesh are fully favourable to solar photovoltaic application. But there has been a very significant progress achieved, mainly due to the absence of supportive policy, strong political will and people's awareness. In Dhaka City mentioned earlier there is massive gap between power supplies (1000-1200 MW) and the demand is 2000 Mw. As a result of this huge deficit, there has been a growing interest among people about the solar PV installations for power supplement.

The country has potential in wind power generation particularly in the coastal areas, although there is still lack of reliable wind speed data. Bangladesh being an agrarian country produces enormous biomass energy which can be used to generate biogas for clean fuel for cooking and electricity for lighting in the rural areas. However, in spite of enormous potential biogas technology has not been well accepted due to initial expenditure.

In Dhaka Megacity, the application of solar PV systems on the bright roof-tops can generate more than 1,000 MW of electricity (at 105 efficiency with 75 Wp modules) preferably through grid connected PV systems.

Practically the slums are reported to have least attention from electricity supply point of view. Electricity demand for the informal housing is comparatively very low. The roof-tops of these informal settlements can be effectively used for stand-alone PV applications, which are popularly known as solar home systems in the rural areas. Therefore, solar home systems can effectively generate electric power for these settlements. CUS et al. (2005) reported that each slum cluster has 10 households with at least 25 persons. If solar home systems are installed in each slum cluster depending on

the demand, nearly 3-5 MW electricity (600-1,000 Watt in each slum cluster) can be generated through the application of stand-alone PV systems. The electricity demand of the slums can sufficiently be met-up through stand-alone PV installations.

b) Favourable Geophysical Situations in Bangladesh

The geographical location of Bangladesh on the globe, space availability (land availability, available bright roof surface etc.), global horizontal irradiance (GHI), sunshine hours etc. have been identified as the geophysical situation. The receipt of solar radiation depends on the latitude of the area. The geographical location of Bangladesh (between 20034' and 26038' north latitude and between 88001' and 92041' east latitudes) lies in one of the best locations, which is well-supportive to capturing enough solar radiation for electricity generation (Islam, 2005; Hossain and Badr, 2005). Bangladesh is grouped as the first category with best location for PV systems. However, due to lack of financial and technological support, political commitment, it fails to exploit the abundant solar energy at the optimum level.

c) Sunshine Hours and Solar Radiation

From solar energy generation perspectives Bangladesh being located in the suitable global position receives very effective duration of sunshine. The period from November to May has the maximum sunshine duration, and the period from September-October is reasonable satisfactory. Due to the availability of sunshine throughout the year the GHI of Bangladesh is also satisfactory for solar power production. It is calculated that the total yearly amount of solar radiation received over the surface of Bangladesh is at least 2.4X 1014 kWh, while existing electricity generation is 2.0X1010 kWh. Therefore, the availability of solar radiation is 10,000 times of electricity generation (SWERA, 2007). The daily average GHI in Bangladesh is 4.29 kWh/m^2 and the annual receipt of solar radiation of 31 locations of the country is 1,566 kWh/m^2. The SWERE project concluded that non-concentrating photovoltaic systems (stand alone or grid connected roof top) is feasible in the atmosphere of Bangladesh. Similar type of solar PV applications can be appropriate for the Megacity of Dhaka.

XI. Renewable Energy Applications and Businesses in Bangladesh

To achieve the target of making electricity for all citizens of Bangladesh by the year 2020, ensuring reliable and quality supply of electricity at a reasonable price is important. Many initiatives have being undertaken by public, private and NGOs. Nearly 2.5 million solar home systems have been installed in the remote off-grid areas all over Bangladesh through the government owned company IDCOL mainly with the financial assistance to local NGOs (IDCOL, 2014). Grameen Shakti is excelling in implementing solar home systems in Bangladesh. As of 2014, it has installed 1.7 million SHSs in Bangladesh. Like Grameen Shakti many NGOs are providing SHSs micro-loans to people for purchasing solar home systems in Bangladesh. More than 98% return on loan instalment has been made by the consumers as reported by IDCOL's partner organizations (GEF, 2005). Although the installation capacity of solar PV system based electricity (currently around 25 MW and 50 MW by 2 million SHSs installed in Bangladesh) is still very negligible. However, solar PV systems like solar lanterns, solar home system, solar market electrification system, solar water pumping, solar refrigerator, and grid connected PV system; solar-wind hybrid system and solar-diesel hybrid system get popular in Bangladesh.

a) Renewable Energy Service Promotions and Supports s by IDCOL in Bangladesh

Bangladesh government promote and support renewable energy, saving energy and GH emission reduction have been the goals. The legal framework for the support of the renewable energy sources of the country from the government is the Infrastructure Development Company Limited (IDCOL), a project of the World Bank Bangladesh. IDCOL is providing financial support, technological support to the implementing RE projects in Bangladesh. For example GS, BRAC, Rahimaforz etc. get solar panel installation support from IDCOl Bangladesh.

Until 2010, IDCOL has installed nearly 450,000 home systems (mostly off-grid systems) through the partner organizations having a total installed capacity of nearly 25MW (IDCOL, 2014). Grameen Shakti leads the installation process providing more than 60% of the systems alone. Solar home system normally used by the rural households consist of 4 florescent bulbs of 7 W each, 1 black-white TV of 15 W and a radio of 5W As mentioned earlier, one family using this small system can save yearly 290 litters of kerosene by using solar lighting technology and can prevent the emission of 0.76 ton CO_2 per year (SWERA/RERC, 32007). By installing 450,000 solar home systems all over Bangladesh can save 130 million litters of kerosene and 342,000 tons of CO_2 each year. However, the paper identifies has been identified that there is a large power deficit in Bangladesh, but there is a large untapped solar energy potential (favourable geographical situation geographical location on the globe, incidence of global horizontal irradiation, sunshine duration and day length, temperature, available bright roof tops) and the rising concerns of climate change. However CO_2 emission reduction can be done through clean energy (UNFCCC and Kyoto Protocol).

Wide scale used RETs in Bangladesh are shown in the following Table 15:

Table 15 : Wide scale use of RETs (renewable Energy Technologies)

Technology	Number of Units (by 2007)
Solar Home System	Above 1000,000
Improved biomass cooker	3000,000
Biogas plants	25,000
Biomass bracketing machines	100

Source: SWERA, 2010.

RETS technologies demonstrated in Bangladesh are solar water heaters, solar dryers, solar cookers, water lifting wind turbine, wind electricity generators, hybrid generators-solar wind/diesel, grid connected wind turbine, micro hydro generator and LED lamps. IDCOL has invited proposals for developing a 1-2 MW solar panel assembly plant in Bangladesh.

XII. Barriers to Greater Utilization of Renewable Energy Technologies in Bangladesh

There are plenty of barriers hindering (as of 2007) widespread development of potential RETs in Bangladesh. The main barriers are lack of information among the public and policy makers about the renewable energy resources, technical/economic information about RETs; assembly of renewable energy technology components and equipment are currently limited and the high upfront cost at the end user level for renewable energy is a major barrier in Bangladesh. According to the Power Cell (2006) of the Government of Bangladesh, the tentative target for renewable energy utilization by 2020 is shown below Table 16 along with estimates for GHG reduction.

Table 16 : Power Cell targets for RETS

Tentative Target for RETs, 2020 and GHG reduction

Resource	Expected utilization	GHG reduction (million tons of CO_2)
Wind	1000 MW	5.0
Solar	300 MW	0.5
Biomass/Hydro	600 MW	0.6
Co-generation	300 MW	0.3
Total Renewable Energy	3200 MW	6.4

Source: Power Cell, 2006

GHG (Green House Gas) mitigation

The following results for CO_2 reduction have been found for various proposed applications of RETs.

Table 17 : Potential for electricity generation from solar and Wind energy technologies and the scope of CO_2 mitigation by 2020

RET	Indicative Potential	In place of conventional generation using Grid	CO_2 reduction potential ($MtCO_2$/year)
Hydr.o electricity (existing (230 MW)	300 MW	Grid1.4	
Solar Home system	50 W, 2 million	Kerosene & Grid	1.5
Solar lights for the poor	10 w, 2 million	Kerosene	0.6
Wind Diesel hybrid micro grids	100 kW.300	Diesel genset	0.1
PV Diesel hybrid micro grids	100 kW. 300	Diesel	0.1
Wind electricity generation (minimum)	200 MW	Diesel genset	2.1
Grid connected PV (if grid is stable)	200MW	Grid	0.8
Total			6.6

Source: SEWRA, 2007

Table 18 : Potential of thermal energy from Solar and the corresponding scope for CO_2 mitigation by 2020

RET	Application of RET	CO2 reduction potential (MtCO2/year
Solar Water Heaters	1 sq. Km	0.4
Improved biomass cookers 915% more efficient than conventional and biogas disasters	Biomass replacement	1.9
Total		2.3

Notes: Wood/straw produces 3.8 ton CO_2/ton fuel

Source: SEWRA, 2007

XIII. IDCOL's Financing to Various Renewable Energy Programmes in Bangladesh

SHS is a convenient mode of supply power for small electrical loads such as lights, radio, and black & white TV. The supply has proved to be reliable and the systems can be managed in rural areas with little training. The main components of an SHS are a solar panel, a battery, and a charge controller.

IDCOL starts its solar program in January 2003 with the support from International Development Association (IDA) and Global Environmental Facility (GEF) to fulfill basic electricity requirements in the rural areas of Bangladesh. IDCOL provides both grant and refinancing for 50,000 SHS over a period of five-and – half years (January 2003-June 2008). The target was achieved in August 2006, three years ahead of the project completion period and US$2.0 million below estimated project cost of US$20 million. Therefore, the target was revised to finance a total of 200,000 SHS by the year 2009 with additional support from the World Bank, GTZ and KFW (IDCOI, 2014).

Table 19 : Progress with SHS's installation up to January 2007 PO wise installation of SHSs

Participating organization	Number of SHSs Installed
Grameen Shakti	61,309 *GS start its SHS distribution in 1997, before IDCOL support to GS. It is also supplying SHSs to people with its own resources.
BRAC foundation	22,115
Srizony Bangladesh	3,387
COAST Trust	1,270
TMSS	994
Centre for Mass Education and Science	1,263
Integrated Development Foundation	1,255
Shubashati	1,077
UBOMUS	1,620
BRIDGE	698
PMUK	61
RSF	1,600
PDBF	121
HF	139
Mukti Cox's Bazar	76
Other	77
Total	97,062

Source: SWERA 2007.

Many job opportunities have created through SHS program. Through GS, 11,230 people have employed in Bangladesh.

There are 2, 12,481handlooms units and 5, 14,456 handlooms exist in Bangladesh. Here is an opportunity to install SHSs and support handloom people. SHS units may use in the public and private hospitals in Bangladesh. Total numbers of hospitals are 1383 (public hospitals number is 671, and non-government hospitals number is 712) (IDCOL, 2014; SWERA, 2007).

To reduce GHG emission in Bangladesh, IDCOL has massively financing to NGOs for Solar Home System installations. A typical Solar Home System often consists of 4 fluorescent bulbs of 7w each, 1 BW TV of 15 W and a radio of 5W. Normally a home uses Kerosene for Lanterns and charges battery from grid supply at far away locations. Table 16 shows corresponding figures of saving kerosene and reducing CO_2 emission.

Table 20 : CO_2 reduction using Solar Home System

Total No. SHSs	Savings of Kerosene in litters/year	Tons CO_2/year
65,000	19 million	49,000
1,00,000	29 million	75,000

Source: SWERA, 2007

IDCOL renewable energy activities started in 2003 with the Solar Home System (SHS) program. IDCOI also has been implementing solar irrigation pump program, solar PV mini-grad project, solar-diesel hybrid power system for telecom BTS, biomass gasification project, biogas based power plant projects etc. Recently ICOL has launched Improved Cook Stove (ICS) program, with target to disseminate 1 million ICS by 2017.

IDCOL's Solar Home System Program is one of the fastest growing off-grid Renewable Energy Programs in the world. IDCOL, with support from the World Bank (IDA), Global Environmental Facility (GEF), German Technical Cooperation (GTZ), German Development Cooperation (KFW), Asian Development

Bank (ADB), Islamic Development Bank (IDB), Japan International Cooperation Agency (JICA), The Department for International Development (DFID), USAID and Global Partnership on Output –Based Aid (GPOBA) is channelling both grant and credit to the program. As of March 2013, 2 million SHSs with generation capacity of about 100 MW have been installed covering 6% of the population (IDCOL, 2014).

Table 21 : IDCOL Program Benefits (2014)

Program achievement:	3 million SHS
Number of beneficiaries:	13.5 million people
Power generation:	150 MW
Fossil fuel saving:	216,000 ton/yr
CO_2 reduction:	503,000 ton/yr
Job creation:	60,000
IDCOL investment:	USD$ 500 million

Source: IDCOL, 2014.

IDCOL now has a target of financing a total of 6 million SHS by 2017. Till August 2014, more than 3 million SHSs have been installed across Bangladesh (IDCOL, 2014). Around 60,000 SHS are now being installed every month under the program. The total number of beneficiaries is 15 million rural people which is more than 9% of the total population of the country. The existing 2 million solar home systems have reduced consumption of approximately 230,000 tons of kerosene per year and hence, this contributed towards global drive of GHG emission reduction.

IDCOL provides three types of grant and concessionary refinancing support to its (POs): (a) the buy-down grant, provided to the customers to reduce the capital cost of HS; (b) the Institutional Development Grant, provided to Pos for their capacity development; and (c) the refinancing support (up to 80% of the total credit), extended to customers by the POs.

IDCOL follows a unique sustainable business model with commercialization objective for dissemination of SHS ensuring ownership of each stakeholder. Under the structure, customers are required to pay minimum 10% of the system cost net of grant as down-payment. The remaining 90% is financed by a loan from PO (partner organization), which the customers pay over 3 years in monthly instalments. Subsequently, the POs apply to IDCL for refinancing and grant. These subsidy elements of the program are gradually being phased out and more commercial financing are being introduced. Cost efficient standardized technical design, competitive market prices, development of local support industries, customer education, training, development of skilled manpower, stringent quality control & monitoring and services after sales services are other important features of the program. The grant and refinancing are disbursed to the POs. As of March 2013, IDCOL invested more than USD 365 million in its SHS program (IDCL, 2014).

Biogas produced from these plants is being used for cooking purpose in rural households; IDCOL has financed more than 34,000 biogas plants (till April 2014). Total number of beneficiaries under IDCOL program is 153,000. The program saves 82,000 tons of firewood and 1,088 tons of Kerosene every year. In addition, the slurry, by product of biogas plants, being a very good organic fertilizer is used as fertilizer and very good fish-feed. More than, 204,000 tons of organic fertilizer produced every year from these biogas plants and reduce use of 29,000 tons of chemical fertilizer. IDCOL is implementing the program through its 41 Partner Organizations. IDCOL also financed for Improved Cook Stoves (ICS) Program to NGOs in Bangladesh. IDCOL's target is to disseminate 1 million ICS in Bangladesh by 2017 (IDCOL, 2014).

Solar powered irrigation system is an innovative, economic and environmentally friendly solution for the agro-based economy of Bangladesh. ICOL has financed 38 and approved financing of additional 76 solar PV based submersible water pump in different locations of the country. IDCOL has a target to finance 1,550 pumps by 2016. IDCL provides subsidy, soft loan and technical support to ensure effective implementation of the program. IDCOL also financed to NGOs for biomass gasification based power plants

Table 22 : IDCOL Products and Services

Infrastructure Sector	Long-term local and foreign currency loans Debt and equity arrangement Agency services Corporate advisory services Short-term local currency loans
Renewable energy and energy efficiency initiatives	Concessionary credit and grant support Advisory services Technical assistance and quality assurance Capacity development of stakeholders Facilitation in availing CDM benefits
Training programs	Project finance Financial modeling Renewable energy

Source: IDCOL, 2014.

IDCOL has financed a 400 kW biomass gasification-based power plant along with precipitation silica production plant and 250 kW biomasses gasification based power plant. These plants use locally available agricultural residues i.e. rice husk as fuel for power generation. By 2016, IDCOL has a target of financing another 30 biomass gasification based power plants. IDCOL has financed to five biogas power plant, with capacity of 400 kW, 50 kW and others with 6kW capacity, have been financed by IDCOL. Poultry litter is used as feed material in the biogas digesters for gas production and this biogas is used for electricity generation as well as cooking and per boiling system. Electricity generated from the plant is consumed for running poultry farms. Bio-fertilizer produced from the plant is used in crop production and fish farms. IDCOL has a target of financing 450 biogas based plants by 2016 (IDCOL, 2014).

IDCOL concessionary financing for energy efficient brick projects Thousands of traditional fixed chimney brick kilns emit an estimated 9.8 million tons of C_2O per annum, making it one of the worst green-house gas emitters in the country. IDCOL plans to invest around BDT 4,000 million in the energy efficient brick manufacturing sector in Bangladesh by 2020 (IDCOL 2014).

IDCOL Solar Powered Solution for Telecom BTS: IDCOL has financed solar powered solution for 138 telecom base transceiver stations (BTSs) in off-grid areas of Bangladesh. Solar powered solutions provide continuous power supply to ensure uninterrupted voice and data services. IDCOL has financed to Solar Mini-grid Projects in Bangladesh. IDCOL has financed one 100 kW solar mini-grid project in a remote island in the Bay of Bengal. IDCOL's participation in the Solar Mini-grid projects not only supported the efforts of the Government to address the growing infrastructure demand in Bangladesh but also played a catalytic role for attracting private investment in infrastructure projects. In 2013, IDCOL plans to invest further BDT 1 billion in a number of power, telecommunication, transport, social infrastructure and urban environmental projects (IDCOL, 2014).

Through IDCOL more than 70,000 direct jobs have created in Bangladesh. Due to SHSs, students now benefit from extended hours of studies at night in better lighting condition, small businesses enjoy extended operating hours and women feel more secured at night. The existing SHSs installed under the program reduces approximately 528,000 ton of CO_2 annually (IDCOL, 2014).

XIV. Grameen Shakti

Grameen Shakti is a non-profit organization established in 1996 to promote, develop and popularize renewable energy technologies in remote, rural areas of Bangladesh. Currently, GS is one of the largest and fastest growing rural based renewable energy company in the world. GS is also promoting Small Solar Home System to reach low income rural households. It enlighten houses by solar power, cook comfortably by bio-gas.

Table 23 : Grameen Shakti Programs at a Glance as of February, 2015

Description	This Month	This Year	Since Inception
No. of Solar Home System	16,594	33,184	1,583,319
No. of Biogas Plants installed	279	556	30,847
No. of Improved Cooking Stoves	9,767	19,299	910,204
No. of Branches	0	0	1,245
No. of Persons trained	124	238	44,252

Grameen Shakti is providing loans to SHS receivers both GB borrowers and to the non-GB members. Till February 2015, GS has alone installed 1,583,319 solar home systems covering 64 districts in Bangladesh. It is working at the grass roots village level and selling SHS to villagers with credit who pay their SHS prices at an instalment basis over three years. For the solar PV installation, GS selects areas where there is no availability of conventional electricity or areas with low coverage by Rural Electrification Board (REB) or areas with almost no possibility of the extension of rural electrification within 5-10 years period.

Grameen Shakti is working not as a charity rather follows social business model. It has successfully blended technology with social market forces to develop a market based approach to reach the rural people. It does not provide direct subsidies to RE users. It has developed an innovative micro-credit service to RE users to reduce costs and to reach economy scale.

a) Installations of SPV Systems b y Grameen Shakti

Within a period of one and an half decade, it has been able to develop a large number (2500) trained technicians, (mostly women) and altogether 7,000 employees for preparing, installing and taking care of the home systems. It has targeted to empower 75 million people all over the country through renewable energy technologies by 2015 (Grameen Shakti, 2009). It continues to provide solar home systems at a rate of 10,000 systems per month. The price of the SHS is still expensive for the rural poor; (Hackett, 2009). The application of solar PV systems by GS until now includes mostly stand-alone PV systems, SHSs to run CFL lights,

black and white television, mobile chargers, refrigerators for vaccine preservation etc.

Grameen Shakti SHSs is used to light up homes, shops, fishing boats etc. People also used to charge cellular phones, run televisions, radios and cassette players. People also use for operating TVs cassettes, audios, VCPs etc., operational small fans and amplifiers, running computers and cellular phones, running computers and cellular phones and running DC motor driven equipments such as drill machines, soldering irons etc.

GS has introduced micro-utility model in order to reach the poorer people who cannot afford a SHS individually. GS has developed an effective strategy for reaching people in remote and rural areas with solar PV technology. It involves soft credit through instalments which makes SHSs affordable; community involvement and social acceptance; effective after sales service and blending Technology with Market Forces.

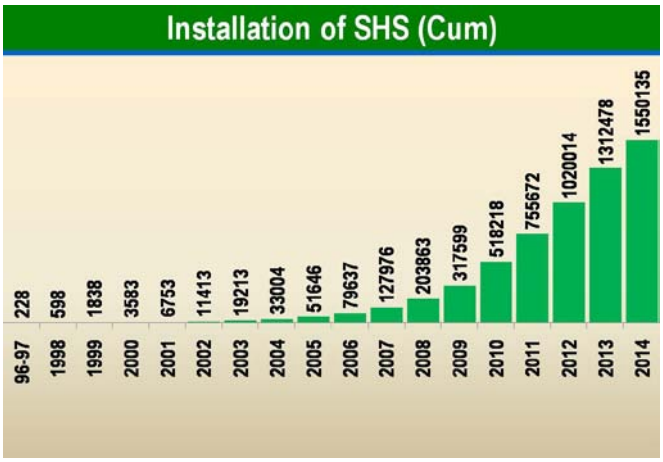

Figure 2

Source: Grameen Shakti, 2015.

Grameen Shakti SHSs users become the owner of an electric power generating and supply system. No need to pay monthly electricity bill in every month. SHSs life span is more than 20 years. There is no load shedding with SHSs. This technology is clean, safe and is environmental friendly & health hazards free energy.

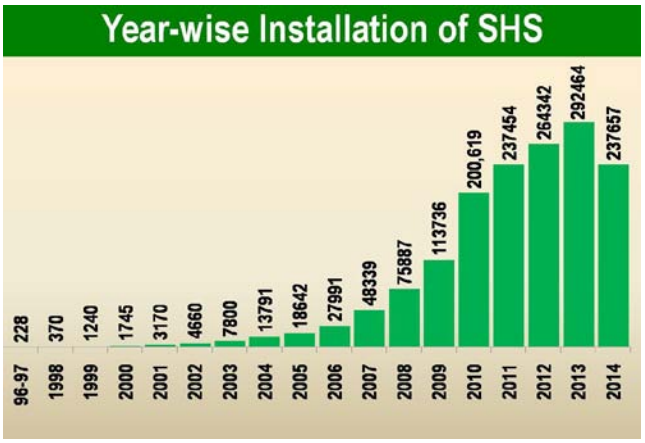

Figure 3

Source: Grameen Shakti, 2015.

b) GS PV Program Approach

Grameen Shakti's PV program targets unprivileged masses who live in remote rural areas of Bangladesh in order to make it easier for rural people to buy a system, GS has designed four soft financing options:

Table 24 : GS Financial Options

Option	Down Payment	Instalments	Service charge (flat rate)
Option-1	15%	36 months	6%
Option 2	25%	24 months	4%
Option-3	15%	36 months (with 36 post dated cheque)	5%
Option-4	1005 cash payment with 4% discount		

Source: Grameen Shakti, 2015

Table 25 : Grameen Shakti package price of LED Lamp solar home system 2014-2015 (price is changeable)

SL.	System Capacity (Watt)	Loads can be used	Equipments supplied by Grameen Shakti	Package price TK.
1	10	2X2.5 watt LED light	A 10 watt panel, 2X2.5 watt LED light, a 15 AH battery, a charge controller, a frame and cables	8,100
2	15	2X3 watt LED light	A 15 watt panel, 2X3 watt LED light, a 15 AH battery, a charge controller, a frame and cables	9,400
3	20	3X3 watt LED light	A 10 watt panel, 3X3 watt LED light, a 20/23 AH battery, a charge controller, a frame and cables	12,000
4	20	3X3 watt LED light	A 20 watt panel, 3X3 watt LED light, a 15 AH battery, a charge controller, a frame and cables	13,000
5	30	2x3 watt LD light and a	A 10 watt panel, 2X2.5 watt LED light, a 30 AH	15,500

		15" LCD/LED TV	battery, a charge controller, a frame and cables	
6	40/42	3X3 watt LED light and a 15" LCD/LED TV	A 10 watt panel, 2X2.5 watt LED light, a 40/45 AH battery, a charge controller, a frame and cables	22,000
7	50	4X3 watt LED light and a 15" LCD/LED TV	A 50 watt panel, 4X3 watt LED light, a 55/60 AH battery, a charge controller, a frame and cables	27,100
8	60	5x3 watt LED light and a 15" LCD/LED TV	A 60 watt panel, 5X3 watt LED light, a 60 AH battery, a charge controller, a frame and cables	30,600
9	63/65	5x3 watt LED light and a 15" LCD/LED TV	A 63/65 watt panel, 5X3 watt LED light, a 70/80 AH battery, a charge controller, a frame and cables	31,600
10	75	6x3 watt LED light and a 12 watt fan and 15" LCD/LED TV	A 75 watt panel, 6X3 watt LED light, a 80 AH battery, a charge controller, a frame and cables	34,100
11	80	7x3 watt LED light, a 12 watt fan and a 15" LCD/LED TV	A 80 watt panel, 7X3 watt LED light, a 880 AH battery, a charge controller, a frame and cables	36,600
12	83/85	7x3 watt LED light, a 12 watt fan and a 15" LCD/LED TV	A 83/85 watt panel, 7X3 watt LED light, a 100 AH battery, a charge controller, a frame and cables	37,600
13	100	9x3 watt LED light, a 12 watt fan and a 15" LCD/LED TV and a 15" LCD/LED TV	A 100 watt panel, 9X3 watt LED light, a 100 AH battery, a charge controller, a frame and cables	41,600
14	130/135	7x3 watt LED light, two 12 watt fans and a 15" LCD/LED TV and a 15" LCD/LED TV	A 130/135 watt panel, 7X3 watt LED light, a 130 AH battery, a charge controller, a frame and cables	46,100
Warranty for different parts off LED Solar Home system Solar Panel: 20 years LED Lamp; 3 years 15 AH Battery: 3 years Change Controller: 3 years				

Source: Grameen Shakti, 2015.

The most popular demand Grameen Shakti's SHSs packages are serial number 3, 4, and 5 items in Bangladesh as mentioned items in the Table 25. In order to reach the poor, GS has introduced a financial model, known as Micro-utility. Till now GS installed more than 10,000 micro utility systems. GS also focuses on demonstration, quality products, and a reliable maintenance service to build awareness and trust of the rural people.

GS has been successful in promoting and constructing both domestic and larger sizes biogas plants to rural villagers. GS Biogas Program has a unique financial mechanism based on credit, which makes biogas plants affordable to the villagers. People use cow dung in their bio gas plants. Biogas technology can be also used with the home wastes. Grameen Shakti provides free services after sales including monthly visits by GS engineers for two to three years. People uses slurry of Biogas plant for organic fertilizer.

Key features of the GS biogas program are: a financial mechanism based on credit, which makes biogas plants affordable to the villagers, plants designed and constructed after one to one consultation with clients. GS provides free consultations after sales service including monthly visits by GS engineers for two to three years. GS uses local masons for constructing biogas plants in the villages. GS links biogas technology to emerging poultry, livestock and agriculture business. GS supported biogas is also using for cooking like natural gas.

Biogas protects women and children from in-door air pollution and related diseases such as coughs, asthmas etc. It helps keep the environment clean and stops the spread of diseases by transforming pollutants into clean energy. It saves fire woods resulted stops deforestation.

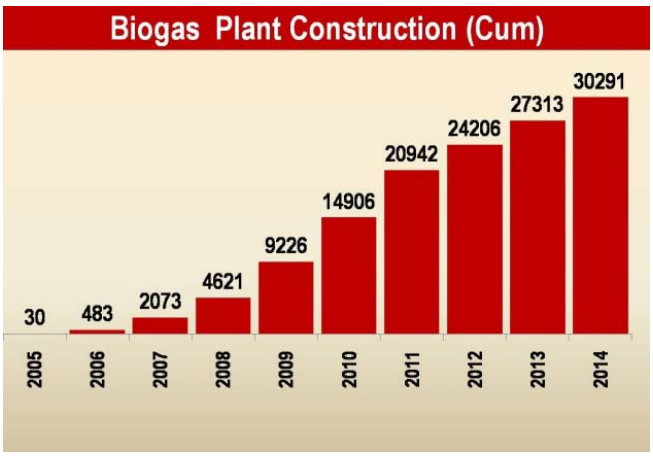

Figure 3

Source: Grameen Shakti, 2015

c) *Bio-gas Program Financial Approach*

Grameen Shakti Bio-gas program has attractive financing system such as:

Option-1: 25% of the total cost is down payment. The remaining 75% is to b e paid in 24 monthly instalments with 8% service charges (flat rate) in 2 years.

Option-2: The buyer can also build his plant by himself, under the supervision of GS Engineers. In this case, half of the technical and supervision fee will be paid as down payment and the rest will be paid after the instalment.

d) *GS Wind Energy Program*

GS is also working in the field of solar thermal project, but it is still in pilot stage. GS installed 4 hybrid power stations (combination of wind turbine and diesel generator) in four cyclone shelters of Grameen Bank in the coastal areas in Bangladesh (Grameen Shakti 2015). The power generated from the wind turbines is connected to the four cyclone shelters. Appliances powered with this system are light, fan, water pump etc.

e) *Grameen Technology Centers*

GS has set up 45 Grameen Technology Centers (GTC). These GTCs are producing SHS accessories by manufacturing these locally. GTCs are also contributing to women empowerment by developing Solar Technicians in the villages. Women members of 5000 SHSs user families are also trained on proper repair and maintenance of their systems. Besides these, 10,000 school students gain awareness about the renewable energy technologies and the environment. GS also trained 300 engineers in order to implement this project smoothly. GS these technicians sign annual contracts with GS for after sales maintenance and become entrepreneurs in the future. Women technicians have already been trained, many of them are assembling SHS accessories at local GTCs, others are providing after sales service.These GTCs train renewable energy entrepreneurs and link them up with different technical and financial institutions.

Financing Solar Home Systems (Grameen Shakti 2015)

- 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

GS research and development intents to develop and fabricate the solar accessories (charge controller, lamps, DC to DC converters etc.) locally in order to reduce the total system cost. Grameen Shakti has already developed Charge Controller, DC-DC Converter, DC Ballast for fluorescent lamp, Mobile phone charger products at low cost

f) *GS Improved Cooking Stoves contributes*

GS improved cooking stoves contributes to 50% less fuel cost, women protected from in-door air pollution, no blackening, no heat from stove. GS has become interested in ICS because it helps women and makes their lives easier. GS sees a potential market of at least 2 million ICSs in the first three years of the program. GS plans to depend on two types of local players for expanding Improved Cook Stoves - local technicians and local manufacturers. GS has already trained more than 1000 local youth especially women to make, sale and repair ICSs. GS plans to train more technicians in the next phase .These trained technicians train others as well as produce and commercialize improved cook stoves on behalf of Grammen Shakti. Many of them have started their own business in arrangement with GS.

Figure 4

Source: Grameen Shakti, 2015

g) *Bio-fuels*

India established the first biodiesel produce from Jatropha plant in Hyderabad of Andra Pradesh (GTZ, 2008). It is expected that at least 2.5 m. tons of biodiesel can be supplemented to the total demand of around 50 m. tons for Indian vehicles. Jatropha plants grow in the dry-arid part of the Indian State has promoted the local's income generation. Grameen Shakti has started to cultivate Jatropha on a plot basis in Dhaka in 2010, but it is yet not cultivate at mass scale.

h) *Social Business and Nabin Udoykta Program of Grameen Shakti- a new Dimension*

All the activities of the organization Grameen Shakti executes are fully related to social business

perspective. It is a new category of cause-driven business. The company must cover all costs and make profit, at the same time achieve the social objective. In a social business, the investors/owners can gradually recoup the money invested, but cannot take any dividend (profit) beyond that point. Grameen Shakti follows all seven principles of social business.

Grameen Shakti has been attached to 'Nobin Udyokta Program' of Nobel Laureate Prof. Muhammad Yunus, a very promising project to bring new young entrepreneurs in the light. Prof. Muhammad Yunus has given permission to include the children (2nd generation) of Grameen Bank Borrowers from Birulia, Ahshulia and Dhamshona Union under Savar Upazilla of Dhaka district in the Social Business as well as Nobin Udyokta (New Entrepreneurs) Program.

The activity of investment in the different promising project of Nobin Udyokta has already been started in the Grameen Bank Area of above mentioned unions under Nobin Udyokta program executed by Grameen Shakti. Till now, 6 Nobin Udyokta projects have been presented in Executive Design Lab and approval for investing. Tk. 1.4 million has been invested by GS. Four Nobin Udyokta have received Nine Hundred Thousand Taka till now. These projects include tailoring, textile business, telecom service, grocery shop, dairy farm etc (GS, June 2014). Rest of 2 projects is now in the process to be invested as early as possible. Moreover, more than 10 promising project are in pipe line to be presented in Executive Design Lab in near future. There is a plan to invest 5 million Taka among 20 Nobin Udyokta (New Entrepreneur) by December, 2014 and 50 million Taka among 250 Nobin Udyokta by 2015 (Grameen Shakti, April, 2015).

Table 26 : Programs at a Glance February, 2015

Total Office	**1528**
Branch Office	1245
Grameen Technology Centre	34
ICS Production Center	67
D-Ionized Water Plant	1
Number of districts covered	Covered all districts
Number of Upazilas covered	508 Upazila
Number of villages covered	50,000 villages
Total beneficiaries	Around 17.67 million people
Total employees	11,230
Total installation of SHS	1,583,319
Total Number of Improved Cook Stove (ICS)	910,204
Total biogas plant constructed	30,847
Total installed power capacity	63.33 MWp
Daily power generation capacity	171.00 MW-hr
Installation rate	Over 20,000 SHSs/ month
Installation of micro utility systems	Over 9,605 system
Number of trained technicians (Mostly woman technicians)	22,822 technicians
Number of trained customers (Mostly woman)	839,725 users
Full Paid customer (ownership)	604,694 customers
User under maintenance agreement (After 3 Years)	44,759 customers
Future plan- total installation of SHS by 2015	2 million
Future plan- biogas plant construction by 2015	100,000
Future plan- Improved Cooking Stove construction by 2015	2 million
Green Jobs Creation by 2015	100,000

Source: Grameen Shakti, February, 2015

XV. National Energy Policy

The first National Energy Policy (NEP) of Bangladesh completed and gazetted in 1996 was adopted mainly with the aim of achieving sustainable economic growth and developing sufficient energy for different sectors (Islam et al. 2006; Islam, 2005). The guidelines of the renewable energy were mentioned in the NEP document. Later, the government adopted Private Power Generation Policy in order to promote private sector participation in power generation. In 1996, import duty and value added tax from solar PV and wind turbines were withdrawn by the government. In April 2004, Bangladesh Energy Regulatory Commission (BERC) was established and started functioning. The major objectives of the renewable energy policy mentioned in the NEP 2004 are targeted to provide energy for sustainable economic growth to meet the energy needs of different zones of the country, ensure environmentally sound sustainable energy development programmes causing minimum damage to environment, encourage public and private sector participation in the

development and management of the energy sector, to bring entire country under electrification by the year 2020, to ensure reliable supply of energy to the people at reasonable and affordable price and too develop a regional energy market for rational exchange of commercial energy to ensure energy security (MPEMR, 2004).

The Renewable Energy Program in Bangladesh has emphasized on the exploitation of solar, wind, biomass gasification, biogas and hydro energy. The major objectives of the renew able energy policy aim to exploit potential RES and disseminate RETs in the rural, peri-urban and urban areas; to inspire private sector investment in RE; to promote clear energy for CDM etc. The policy has targeted to develop RES to meet 5% of the total power demand by 2015 and 10%by the year 2020 (MPEMR, 2008).

XVI. Recommendations

RETs along with technologies for energy conservation and energy efficiency can help overcome energy shortages and lead the country to progress provided necessary steps are taken now without delays. Solar radiation is excellent for all locations of Bangladesh. Large scale utilization of solar and wind energy should help energy security in the face of impending energy crisis from dearth of conventional energy supply. Renewable energy public education could be included in the formal and non-formal adult education in Bangladesh. On going SHS program should be strengthen to enable installation of 500,000 units by 2020

The program for biogas project and biomass cooking stove can solve rural firewood cooking problems so these two technologies can be promoted through public extension agencies, and green NGOs in Bangladesh. For power supplement, the roof-top application of solar PV systems could be promoted in urban areas of Bangladesh. The government sponsored Infrastructure Development Company (IDCOL) has to initiate financing (micro-credit) for solar home systems in the urban slums (like off-grid remote areas). In order to promote sustainable wind power generation, an efficient management system and strong coordination among the respective authorities have to be ensured. For biogas plant installation, village cooperatives can be created to promote the technology among the villagers. Funds for renewable energy projects have to make available along with additional resources for innovative activities of RETs.

Many problems are suffering by the coastal energy users. Therefore, the community institutions could be engaged and financed for developing Wind Pump Energy infrastructure facilities around the coastal areas in Bangladesh.

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