www.serd.ait.ac.th/reric

Effective Solar Photovoltaic Activities in Bangladesh

M.R. Islam*[1], M.G. Rabbani*, M.D. Hossain[+] and M.F. Rahman*

Abstract – *The amount of nonrenewable energy resources of Bangladesh is very limited. The country is facing acute energy crisis and serious desertification problem in rural areas. This problem can be solved by using renewable energy as a primary source of energy in rural areas. Bangladesh is endowed with vast solar insolation and receives an average daily solar radiation of 4-6.5 kWh/m^2. Solar photovoltaic (PV) are receiving interest for providing electricity to households and small business enterprises in off-grid rural areas. Activities on the development and promotion of solar energy technologies have been going on for one decade have led to a start of large scale utilization of solar PV systems. The development and trial of systems are mostly funded so far by donor agencies in collaboration with government and non-government organizations (NGOs). This paper reviews effective solar PV activities in Bangladesh in terms of its implementation, research and development. More than 170,000 Solar Home Systems (SHSs) of a total capacity around 8.67 MWp, 12 centralized AC power supply and 11 solar water pumping system installed so far in off-grid rural, hill tracks and coastal areas in Bangladesh have been considered for assessment.*

Keywords – Bangladesh, nonrenewable energy, photovoltaic, solar insolation, sources.

1. INTRODUCTION

Bangladesh lies in the northeastern part of South Asia between 20º34´ and 26º38´ North latitude and 88º01´ to 92º42´ East longitude with an area of 147,570 km^2 [1] and a population density of about 1016 persons/km^2. Apart from a few city states, its population density is considered as a matter of concern in the world. Its population, however, are dispersed evenly across the country except for the hilly southeastern districts. The growing pressure of increasing population added to the stress on natural resources.

Bangladesh's per capita energy consumption is very low, the lowest within the Indian subcontinent. The energy consumption value of year 2004 stood at 227 kgOE, compared to 500 kgOE for India, 475 kgOE for Pakistan, 400 kgOE for Sri Lanka and 450 kgOE for South Asia, and it was much below the world average of 1680 kgOE [1], [2]. The per capita generation of electricity is only 165 kWh which is very low compared with even other developing countries. Total primary energy consumption in 2004 was 30.70 MTOE and the energy consumption mix was estimated as: indigenous biomass 60%, indigenous natural gas 27.45%, imported oil 11.89%, imported coal 0.44% and hydro 0.23%. Various marketing companies under the Bangladesh Petroleum Corporation (BPC) distribute kerosene and diesel throughout the country at a uniform tariff rate set by the government.

Natural gas is currently the only indigenous non-renewable energy resources of the country that accounts for 73% of commercial energy of the country. The cumulative efforts of exploration for oil and gas resources in Bangladesh has resulted in the discovery of 23 gas fields of various sizes, having a total gas initially in place (GIIP) of 28.619 TCF, and initial recoverable reserve of 20.63 TCF. Out of this, about 7.42 TCF has been produced and 13.21 TCF remains up to December 2007. Yearly natural gas production is shown in Figure 1 [3].

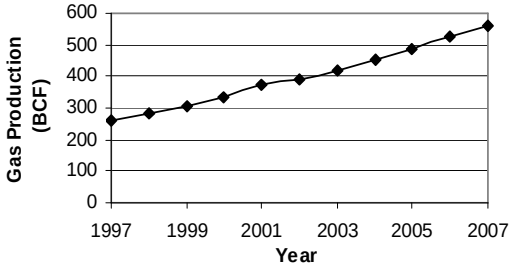

Fig. 1. Year-wise natural gas production.

Currently, the country has only one coal mine operation project at Barapukuria in Dinajpur district. The project has a target to provide 1.0 million tons of coal per annum from the Barapukuria coalfield. It is planned that 0.7 million tons of coal will be utilized to produce electricity in the Barapukuria thermal power plant and the rest will be used as fuel for brick field and other purposes.

Up to June 2007, the total installed electricity generation capacity was 5269 MW with 3872 MW in public sector and 1397 MW in private sector. In the public sector, a good number of generation units have become very old and have been operating at a much-reduced capacity. As a result, their reliability and productivity are also poor. For the last few years, actual demand could not be supplied due to shortage of available generation capacity. The scenario of maximum demand and maximum generation of electricity is presented in Figure 2 [4], [5].

* Department of Electrical and Electronic Engineering, Rajshahi University of Engineering and Technology, Rajshahi-6204, Bangladesh.

+ Department of Electronics and Telecommunication Engineering, Rajshahi University of Engineering and Technology, Rajshahi-6204, Bangladesh.

1 Corresponding author;
Telefax: + 88 0721 750356.
E-mail: rabiulbd@hotmail.com

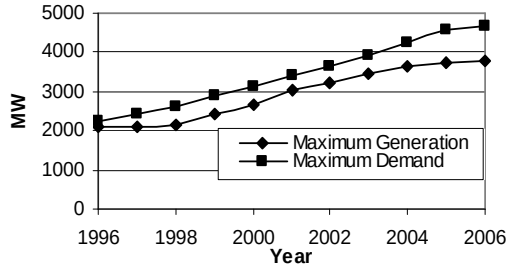

Fig. 2. Maximum demand and maximum generation of electricity.

About 43% of the total population has access to electricity. According to the base forecast of Power System Master Plan drawn up in 2005, the maximum demand in 2020 would be 13,993 MW. The expected demand of electricity is shown in Figure 3 [5].

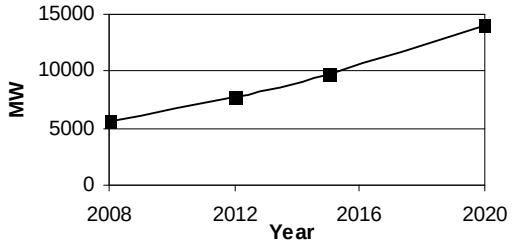

Fig. 3. Expected demand of electricity.

The generation of electricity from natural gas was 87.25 percent of total generation by June 2007. The country is harnessing hydropower from one power plant, located in Kaptai. Although the total potential of the resource is about 1000 GWh/year only a part of it is actually being harnessed. The share of fuel to generate electricity is shown in Figure 4 [5].

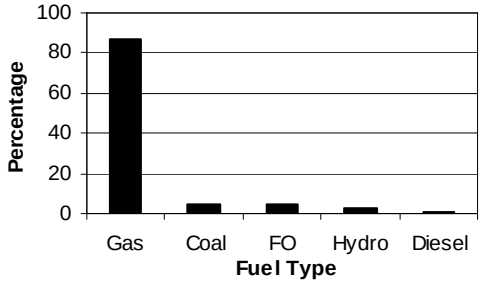

Fig. 4. Total generation based on fuel type.

A major portion of the population located in off-grid areas will not be able to get electricity in the foreseeable future due to several constraints, including low consumer density and inaccessibility. It is expected that Renewable Energy Technologies (RETs) can play a significant role in the far-flung remote locations of Bangladesh. Bangladesh is at the very early stage of utilization of non-conventional and renewable energy resources. Availability of advanced technologies has broadened the scope of application of the renewable energy today.

2. SOLAR INSOLATION

The location of Bangladesh is ideal for solar energy utilization. Daily average solar radiation varies between 4 and 6.5 kWh/m^2 and annual solar radiation availability in Bangladesh is as high as 1700 kWh/m^2. Different research and development organizations, institutes and universities are collecting solar insolation at different parts of Bangladesh. Solar insolation data can be found from the following sources:

- Renewable Energy Research Centre (RERC), Dhaka University is the only source that has long-term measured data of Dhaka city in Bangladesh.
- Bangladesh Meteorological Department has 34 sunshine recording stations situated generally in towns and cities.
- Department of Mechanical Engineering, Bangladesh University of Engineering and Technology, also has time series data of Dhaka city.

Apart from the above-mentioned sources, few other organizations or institutes have also measured time series of global radiation, direct or beam radiation, diffuse radiation, sunshine hours and temperatures of different parts of the country. Monthly global solar insolation at different cities of Bangladesh and daily average bright sunshine hour at Dhaka City are presented in Figures 5 and 6, respectively [6], [7].

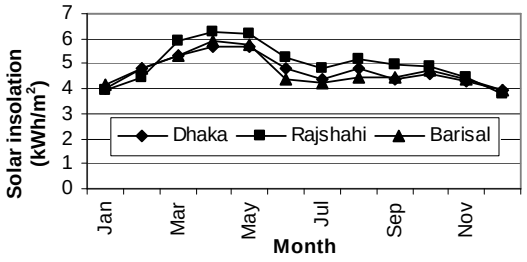

Fig. 5. Monthly solar insolation of different districts (Recording period 1988-98).

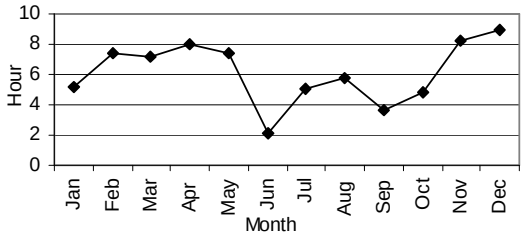

Fig. 6. Average bright sunshine hour of Dhaka City (Recording period 2003).

3. SOLAR PHOTOVOLTAIC

The role of PV generated electricity for various applications ranging from domestic supply, water pumping, street lighting, telecommunication networks and navigational aids has increased tremendously over the last few years as the cost of the module has dropped dramatically making it competitive with conventional systems in some locations.

Solar Home System

Kerosene is used for lighting purposes in 84.73% households of Bangladesh [1]. With all the possible attempts on the part of Bangladesh Power Development Board (BPDB) and Rural Electrification Board (REB) it will not be possible to reach electricity to all villages,

islands, coastal areas, hilly areas and other inaccessible parts of the country. As Bangladesh is blessed with sunshine, PV technology may serve as a great booster for rural electrification.

Among the government departments, the Local Government Engineering Department (LGED) has played the leading role in demonstrating renewable energy technologies in Bangladesh. The goal of Sustainable Rural Energy (SRE) project of LGED was to develop community-based models of renewable energy as an alternative source of rural energy in the off-grid areas of Bangladesh. Up to September 2007, LGED installed diversified solar PV installation of capacity 40.5 kWp in different off-grid parts of Bangladesh. Through Japan International Cooperation Agency (JICA) assisted cyclone shelter project, LGED has established more than 15kW of solar PV system in several cyclone shelters in coastal districts of Bangladesh. LGED has also installed Solar Lighting Systems (SHLSs) with a total capacity of 2.64 kW at Kutubdia, Chokoria of Cox's Bazar and Banskhali, Anwara of Chittagong district for street lighting purposes. In each of the cyclone shelters, the solar installations have been designed to operate 18 lamps and one TV. SRE has installed 2.6 kWp stand alone SHS in 35 houses of Baliadangi village in Thakurgaon district and 1.7 kWp SHS to a cluster village in Sherpur. Installation of 0.225 kWp solar lighting system has increased tourism facilitates at Goznee resort, in Sherpur. Demonstration of total 1.08 kW SHLSs for tribal community was selected at the village Dighalibak under Rangamati Sadar Upazila of Rangamati Hill Tract district. LGED had a Solar Lantern Programme for rural poor house holds at Kalihati of Tangail district with an installed capacity of 1 kWp. Solar PV produces sufficient energy for all offices at Ambaria Union Parishad complex at Ambaria Union in Khoksha Upazila under Kushtia district. The solar PV flood light has also been installed by LGED with a solar panel capacity of 1.8 kW for pisciculture development at Dhala Upazila in Netrokona district. LGED installed 1.5 kW solar PV system at Kamarul Health Clinic at Kamarul in Terokhada Upazila under Khulna district. Solar electricity replaced previous diesel generator and provided modern facilities like operation theater (OT), refrigerator for preservation of vaccine, blood, enhanced modern medical services among the remote locality, etc. [7]. The Institute of Fuel Research and Development (IFRD) under Bangladesh Council of Scientific and Industrial Research (BCSIR) has installed 16 SHLSs of 0.80 kWp capacity [8]. Bangladesh Center for Advanced Studies (BCAS) has installed SHLSs in different districts for health care purposes. BPDB has installed 2300 SHSs of total capacity 80.32 kWp and 30 solar street lighting system of capacity 2.25 kWp at different remote areas of Rangamati and Banderban district for the purpose of street lighting, health care centre electrification, water pumping, and rural home electrification. Up to June 2007, REB installed 233 kWp under different Palli Bidyut Samities of Bangladesh [9], [10].

Infrastructure Development Company Ltd. (IDCOL) promotes SHSs under the Rural Electrification and Renewable Energy Development Project (REREDP) through 15 partner organizations (POs) namely: Grameen Shakti (GS), Bangladesh Rural Advancement Committee (BRAC) Foundation, Srizony Bangladesh, Coast Trust, Thengamara Mahila Shabuj Shangha (TMSS), Integrated Development Foundation (IDF), Centre For Mass Education in Science (CMES), Upokulio Bidyuatayon O Mohila Unnayan Shamity (UBOMUS), Shubashati, Bangladesh Rural Integrated Development For Grub-Street Economy (BRIDGE), Padakhep Manbik Unnayan Kendra, Palli Daridra Bimochan Foundation, Hilful Fuzul Samaj Kalyan Sangstha (HFSKS), Mukti Cox's Bazar, and Rural Services Foundation (RSF). Over 147,577 households have been brought under IDCOL's Solar Programme.

GS has installed 120,000 SHSs till January 2008 with an installation capacity of 6.00 MW. Individual SHS capacity of GS, ranges from 30-128Wp [11]. Up to September 2007, with support from WB/GEF/GTZ/BRAC, installed 1.38 MW Stand alone SHS provided electricity in rural off-grid areas and served 26,600 beneficiaries [12]. Summary of installation of SHSs by different organizations in Bangladesh is shown in Table 1.

Solar Mini-Grid System

For the first time in Bangladesh, SRE project has successfully completed solar market electrification in a rural market at Gangutia under Shoilkupa Upozila in Jhenaidah district. Centralized solar power unit replaced previous diesel power generator, increased average two merchandizing hours of connected 50 shops including grocery, tailor, mobile charging, tea stall, food processing industry, health center, etc. LGED has installed another centralized solar AC power unit of capacity 5 kWp at Sairakhali Jaldaspara is a remote sea-shore and off-grid area located in Fariakhali union under Chakaria upazila in Cox's Bazar district. The purpose of this mini-grid system is to give access to electricity for coastal community through SRE project. The 5 kWp centralized AC solar power unit was the mile stone intervention of mini grid system in our country. United Nations Development Programme (UNDP) supported SRE has installed another centralized ac power system at Dhala Uazila in Netrokona District. SRE under LGED with the finance from UNDP and Ministry of Environment and Forests (MoEF) demonstrated 10 kW Wind-Solar hybrid power generation unit in the island which is the first hybrid model in the country. Demonstration of a 10 kW Wind-Solar hybrid power system at St. Martin's Island facilitates biodiversity and conservation research works and promotes ecotourism infrastructures. BPDB is currently implementing Chittagong Hill Tracts Solar PV Electrification Project and has installed 7 sets of centralized solar PV power plant of capacity 28 kW. Rhimafrooz Batteries Ltd. completed Community Based Rural Village Electrification Project in the Hilly regions of Khagrachari district. The project includes centralized ac power system of capacity 1.2 kW [7].

Table 1. Summary of solar lighting systems installation.

Name of Organization	Description of Installation	Capacity (kWp)
LGED	SHLSs and SHSs for lighting and other appliances like TV, radio, refrigerator etc.	25.98
BPDB	30 solar street lighting systems and 2300 SHSs	82.57
REB	Installation under different Palli Bidyut Samities (PBS)	233
GS	120000 SHSs all over Bangladesh	6000
BRAC	26600 beneficiaries (SHSs)	1380
RSF	7269 SHSs	302.50
CMES	796 SHLS	39.80
TMSS	1149 SHLSs	64.53
IFRD of BCSIR	16 SHLSs	0.80
BCAS	5 solar health care	2.265
BRIDGE	1525 beneficiaries (SHSs)	55
Coast Trust	532 SHLSs	26.60
IDF	601 SHLSs	30.05
Micro Electronics	700 SHLSs	39.31
HFSKS	720 beneficiaries (SHSs)	39.6
Mukti Cox's Bazar	343 SHSs	13.29
Srizony Bangladesh	1710 SHLSs	85.50
Rhimafrooz Batteries Ltd.	16 SHLSs in the Char area of Kurigram District	0.12
RERC	1 SHLS, PV lantern, fan, refrigerator	0.28
SIEMENS Bangladesh Ltd.	1000 SHSs, 3 SHLSs and 2 solar health care	51.26
Singer Bangladesh Ltd.	40 SHSs	2
UBOMUS	3078 SHSs	153.9
SHUBASHATI	592 SHLSs	29.60
ANANDO	35 SHLSs	3.75
First Bangladesh Technologies Ltd. (FBT)	93 SHSs	4.035
Total- 1,69,149 SHSs/ SHLSs and 7 solar health care		8.67 MWp

Table 2. Summary of solar mini-grid systems.

Name of Organization	Description of Installation	Capacity (kWp)
LGED	Centralized AC electrification of 45 shops, 3 food processing small industries, one health care centre and one bazaar mosque	1.8
	Centralized AC power unit at Sairakhali Jaldaspara of Chakaria Upazila in Cox's Bazar District	5
	Centralized AC power system at Dhala Upazila of Netrokona District	1.4
	Wind-solar hybrid power system at St. Martin's Island	10
BPDB	7 sets of centralized solar PV power plant under Hill Tracts Solar PV Electrification Project	28
Rahimafrooz Batteries Ltd.	Centralized AC power system	1.2
Total- 11 centralized AC power system and 1 wind solar hybrid power system		47.4

Solar Water Pumping

There is scarcity of safe drinking water in rural areas of Bangladesh. The problem becomes very acute during the dry season, when water level goes down and most of the earthen well dry up. Sustainable rural energy addressed this intervention (first time in Bangladesh) by installing four submersible solar water pumps at the four villages in Barind region. This system has 6kWp solar PV consequently it could lift about fifty thousand liters of water per day from an average depth of fifty meters. LGED has installed a solar water pumping system at Prantik lake tourist resort of capacity 0.3 kW which can discharge up to 23000 liters/day. BPDB has installed two sets of SPV submersible water pumps of 1.8 kWp each at Thanchi and Juraichari Upazila of Rangamati district with a lifting capacity of 50,000 liters/day [7].

Bangladesh Atomic Energy Commission (BAEC) also installed solar pumping system in Tangail and Savar. IFRD under BCSIR has a Solar PV Water Pumping project at BCSIR center, Dhaka of capacity 220 W for demonstration purposes. RERC has installed a PV pump of 100W in its energy park [8]. The summary of solar water pumping activities is shown in Table 3.

Rural ICT

Access to information and modern communication is a prerequisite for the development of a country. Remote areas do not have any access of electricity in Bangladesh. So the people in the remote areas cannot use computer and internet. To provide the computer facilities in remote places GS decided to install computer training centers powered by solar PVs. Under this program GS already installed six (6) computer education centers in Kutubdia, a remote island of Bangladesh, Shakhipur, Dacope, Kalihati, Patharghata and Cox's Bazar. Another successful GS venture is Polli Phone which allows people in off-grid areas the facilities of telecommunication through SHS powered mobile phones.

Table 3. Summary of solar water pumping systems.

Name of Organization	Description of Installation	Capacity (kWp)
LGED	4 submersible solar water pumps of lifting capacity 50000 liters/day at Barind region of Greater Rajshahi District	6
	Solar water pumping system of discharging capacity 23000 liters/day at Prantik Lake tourist resort	0.3
BPDB	2 sets of SPV submersible water pumps of lifting capacity 50000litres/day at Thanchi and Juraichari Upazila of Banderban and Rangamati District, respectively	3.6
BAEC	Solar Pumping at Savar of capacity 18000 gallons/ day	1.4
	Solar Pumping at Shiloa tea estate in Moulavibazar district of capacity 60 GPM	2.33
IFRD	SPV water pumping project of BCSIR centre, Dhaka for demonstration purposes	0.22
RERC	SPV water pump for research purposes in it's energy park	0.1
Total- 11 solar water pumping systems		13.95

Bangladesh Telegraph and Telephone (T and T) Board has installed a solar-powered telephone exchange of capacity 1.2 kWp. Grameen Phone, a leading cell phone operator of Bangladesh, also has a few solar-powered base stations where grid electricity is unavailable. To develop an Information Technology (IT) culture and related infrastructure in renewable way in remote off-grid areas, SRE took up Solar PV programme at Kutubdia Upazila Engineers office under Cox's Bazar district to run a computer and a printer by solar power from 0.375 kW standalone solar PV system. This will facilitate computer-based official activity in off-grid areas. LGED has also installed a battery charging station and distant communication centre at Galachipa Upazila in Patuakhali district of capacity 1.8 kW to make modern communication available to the islanders [7].

4. RESEARCH AND DEVELOPMENT ACTIVITIES

There are seven public technical universities and three large research centers in Bangladesh, where feasibility studies and innovative research works in the field of RETs may be carried out for available renewable energy resources. They have technically sound human resource but lack of sufficient financial support. Some research and development activities in various fields of RETs have been carried out in these universities, research centers and in some NGOs.

Government Organizations

LGED is one of the leading organizations in the public sector in Bangladesh which is continuously striving for improved management of geographic information needed for its activities. Geographic Information System (GIS) technology offers an exciting potential in identifying locations of markets, Asrayon, UP complex in off-grid areas along with the demands. IFRD under BCSIR engaged in conducting Research and Development in the field of RETs. The institute has installed SHSs, SHLSs and solar PV water pumping system for demonstration and feasibility study [7]. In 1981, the University of Dhaka set up the RERC and from the beginning till now RERC has taken up different research projects in which teachers, researchers and students of the Faculties of Science and Biological Sciences are involved. Research have been carried out on solar radiation, flat thermal collectors, concentrating parabolic collector (CPC), water heaters, solar cookers, Fresnel concentrating collectors, schottky-type solar cell preparation, battery charge controller, PV lantern design and fabrication, PV water pump, PV refrigerator, PV stand-alone residential system.

BAEC launched a number of PV pilot projects to assess their technical feasibility and social acceptance and to determine the potential for local manufacture of balance of system components. These applications included pumping, lanterns and power for cyclone shelters, hospitals, mosques, and a village. System sizes ranged from a few watts to 2.3 kWp.

NGOs

CMES has carried research and development activities on solar cookers, solar water heaters, solar dryers, SHSs, etc. It has recently established its ''Solar Lab'' to take up adaptive research on accessories of solar PV systems, such as fluorescent light ballasts, charge controllers, inverters, income generating appliances like sewing machines, drilling machines, etc. [12], [13]. The institute also installed pyranometer for solar data logging. TMSS and BRIDGE are also involved in research and development activities. Prakaushali Sangsad Ltd. (PSL) carried out research on optimal design of DC luminaries for solar PV application. From the research outcome GS has developed a production unit to fabricate lamp inverter, charge controller, DC-DC converter, mobile phone charger, and inverter. The summary of research and development activities is shown in Table 4.

5. BARRIERS FOR COMMERCIALIZATION

Renewable energy technology is a comparatively new technology for the rural people. Rural people have lack of idea about Sustainable Energy. So awareness development program can assist the market development activities. Demonstrations can be arranged in a public gathering place like market, exhibition, school and college campus to build up the awareness for renewable energy technology and thus convey the massage among mass people. At the same time the customers must be assured of post sales service by skilled technicians whenever they need. The approach of promoting photovoltaic technology in Bangladesh has been different from other countries like India, Nepal and countries in Latin America. One important difference is that Bangladesh has taken a more commercial approach than those countries where number of systems installed are much higher but the programs are heavily subsidized by the government and donors. NGOs working in Bangladesh are not sufficient or they do not

have enough financial backup to promote the use of sustainable energy in the extreme rural areas. Installation and maintenance cost of SHS are high due to bad communication and scattered localities. The financing sources of the country are not interested in renewable energy technology. So, source of financing is often one of the major barriers of adopting SHS in Bangladesh. About 80% of its cost is due to the price of PV module and the battery. In that case, if size of the system is reduced by providing LED instead of DC fluorescent lamp, price of the system could be significantly cut down to affordable limit. To address this intervention SRE has installed five hundred LED based home systems. Some of the system appliances were DC LED lamp and some of them were LED lantern. Before wide dissemination of this new design the project will be closely monitored by some NGOs. If successful, those LED-based solar home system would be a landmark to foster SHLS. Apart from this, to make this new technology successful, awareness must be created among mass population and skilled manpower for this sector also must be prepared

Table 4. Summary of research and development activities.

Organization	Activities
GS	Local manufacturing of all balance of systems components (like charge controller, cable, inverter, converter, etc.).
CMES	Adaptive research on accessories of solar PV systems (like fluorescent light ballasts, charge controllers, inverters), solar data logging.
IFRD	Feasibility study on research and development of solar PV and conducting research and testing on solar equipments.
PSL	Research on optimal design of dc luminaries for solar PV application.
RERC	Research on solar radiation, preparation of different types of solar cells, battery charge controller, PV lantern design and fabrication, etc.

5. CONCLUSION

The energy scenario is worsening day by day. The fuel import bill is over 70% of the country's total export earnings. Diesel generators are widely used, but these are highly polluting and have a short and costlier life-cycle, requiring frequent maintenance and costly parts. The inadequate and unreliable electricity supply, scarcity of firewood and cooking gas, pollution, and rising costs have led to a crisis which is impossible to be solved by relying on nonrenewable sources and manipulating the power supply. The frightening prospect of scarce of non-renewable energy sources in a strife torn world presents one of the major concerns of mankind today.

The Government of Bangladesh (GOB) has vision to electrify the whole country within the year 2020. More than two-thirds of the land area is grid-free. In such grid-free and remote areas where household density is very low, PV power sources are regarded as both very attractive and cost effective with competitive merits at the present PV cost, and PV should play an important role in supplying their energy needs in a most cost effective manner compared with other conventional energy sources. The potential of these renewable energy sources remains practically untapped. Solar energy interventions replace fossil fuel and directly reduces considerable amount of green house gases eventually and keeps our environment healthy. Bangladesh is at the very early stage of utilization of non-conventional and renewable energy resources. Availability of advanced technologies has broadened the scope of application of the renewable energy today. Solar PV program of different government bodies (BPDB, LGED, REB) are basically subsidy driven. The Government of Bangladesh lifted import duty and Value Added Tax (VAT) from solar PV. Building in Global Environment Facility (GFF) and Clean Development Mechanism (CDM) will help expedite the preparation of bankable projects of PV system. Such projects would ultimately benefit the people living in remote and grid-free areas to light up homes, shops, fishing boats, charge cellular phones, run televisions, radios and cassette players etc., and mitigate greenhouse gas emissions. PV systems have become increasingly popular among users because they present an attractive alternative to conventional electricity such as no monthly bills, no fuel cost, very little repair, maintenance costs, easy installation, etc.

REFERENCES

[1] Chowdury, A.J et al. 2007. *Statistical Year Book of Bangladesh-2006*. 26th Edition, Dhaka: Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh.

[2] Islam, M.N. 2003. Energy policy and energy development strategies for Bangladesh. In *Proceedings of Seminar on the Role of Renewable and Alternative Energy Sources for National Development (SRRAESND 2003)*, KUET, Khulna, Bangladesh, 19-20 December.

[3] Bangladesh Oil, Gas and Mineral Corporation (PETROBANLA). *Reserve of Natural Gas in Bangladesh and Production of Gases in BCF per Annum.* Retrieved June 15, 2008 from the World Wide Web: http://www.petrobangla.org.bd/data_production.php.

[4] Bangladesh Power Development Board (BPDB). 2006. *BPDB Annual Report 2005–2006*. Operation: Installed Capacity, Generation Capability, Demand Served and Demand Forecast, 13-15.

[5] Ministry of Finance, Government of People's Republic of Bangladesh. 2008. *Bangladesh Economic Review* 2007-08. Power Energy: 113-114. Retrieved July 20, 2008 from the World Wide Web: http://www.mof.gov.bd/en/budget/07_08/economic_review/chapter_10.pdf.

[6] Renewable Energy and Environmental Information Network (REEIN). *Available Solar Insolation Data*.

Retrieved June 12, 2008 from the World Wide Web: http://www.reein.org/solar/resource/index.htm.

[7] Renewable Energy and Environmental Information Network (REEIN). *Sunshine duration of 2003 for Dhaka*. Retrieved June 12, 2008 from the World Wide Web: http://www.reein.org/solar/resource/solar_irradiance.htm.

[8] Renewable Energy and Environmental Information Network (REEIN), Solar Installation by IFRD, BCSIR for demonstration and feasibility study, Retrieved June 12, 2008 from the World Wide Web: http://www.reein.org/solar/bcsir/index.htm

[9] Local Government Engineering Department, Renewable Energy Information Network (LGED). *Renewable Energy Development and Energy Efficiency Measure of Bangladesh Power Development Board (BPDB)*. Retrieved May 25, 2008 from the World Wide Web: http://www.lged-rein.org/bpdb.php.

[10] Local Government Engineering Department (LGED), Renewable Energy Information Network. *Solar Energy Program in Bangladesh, Rural Electrification Board (REB), Bangladesh Rural Advancement Committee (BRAC)*. Retrieved June 12, 2008 from the World Wide Web: http://www.lged-rein.org/database.php.

[11] Grameen Shakti. *Programs at a Glance, January 2008.* Retrieved April 22, 2008 from the World Wide Web: http://www.gshakti.org/glance.html.

[12] Islam, A.K.M.S., Islam, M. 2005. Status of Renewable Energy Technologies in Bangladesh. *ISESCO Science and Technology Vision* l: 51-60.

[13] Local Government Engineering Department, Renewable Energy Information Network (LGED). *R and D Organizations, Center for Mass Education in Science (CMES)*. Retrieved May 12, 2008 from the World Wide Web: http://www.lged-rein.org/database.php.