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# Promotion of Solar Energy Use in Bangladesh (September 2006)

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***Abstract*** *- Bangladesh has very limited nonrenewable energy resources of its own. The country is facing energy crisis and serious desertification problem in rural areas. These issues could be removed if renewable energy is used as a primary source of energy in rural areas. Bangladesh is endowed with vast solar insolation. Harnessing energy from the resource appears to be a promising solution for improving the quality of life of rural villagers. The annual solar radiation availability in Bangladesh is as high as 1700 kWh/m$^2$. 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 photovoltaic (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). More than 61,500 solar PV systems of a total capacity around 3 MW and 260 hot box cookers have been installed allover the country mainly in off-grid rural, hill tracks and coastal Bangladesh.*

***Keywords*** **- Nonrenewable energy, quality of life, rural-hill tracks-coastal Bangladesh, solar insolation.**

## 1. INTRODUCTION

Energy is the prime source of human activities in all sectors of life. The importance of energy in economic development is also very critical as there is a strong relationship between energy and economic activity. In Bangladesh 44% of the population live below the national poverty line, and the poorer sections of society suffer most from energy scarcity. According to the Bangladesh Bureau of Statistics Household Expenditure Survey, lower-income households spend a higher proportion of their meager income to meet their energy needs. On the other hand, higher-income households spend a smaller portion of their income to meet their energy demand. Moreover, higher-income households use better quality energy sources (natural gas, LPG and electricity) whereas lower-income households have to use inferior type energy sources (firewood, straw, rice-husk, dung, trash, etc., for cooking, and kerosene for lighting).

Because of lack of purchasing power, low-income households can only meet a part of their total demand, whereas higher-income households can meet their full demand. The quality of life of poor households is affected by unfulfilled demand for energy. In the rainy season many poor women cook one meal a day because of shortage of fuel. Because of shortage of kerosene, many poor families try to complete their normal household activities while daylight lasts. There is a need for a target-oriented program to meet the energy needs of the poor.[1]

In Bangladesh a major portion of the total energy available is consumed in the domestic sector for cooking and lighting. Women are in the forefront of the management of domestic energy. In low-income households women spend a considerable time gathering fuel for cooking. Poor women face a highly polluted environment caused by combustion of inferior types of biomass fuel.

Historically fossil fuel in its solid phase, i.e. wood and coal has been the prime source of energy. The increment in energy global demands due to population growth and 19th century industrial revolution, lead fossil fuel through a transitional phase. World saw their refined liquid phase, oil that is more efficient than wood and coal. More recently world became familiarized with gaseous phase of fossil fuels that is even more efficient. Renewable energy sources such as biomass have also been utilized since the beginning of civilization. By the middle of 20th century, the developed countries to meet their energy needs introduced nuclear power.

The depletion of fossil fuels which contribute to 80% of world's primary energy supply, and environmental impacts associated with presently used energy modes have emphasized the need for an alternate solution to meet global energy needs without inflicting any serious environmental impacts. Renewable energy sources are the answer to these energy and environmental challenges. Renewables such as solar, wind, hydropower and biogas are potential candidates to meet global energy requirements in a sustainable way. Solar energy has the potential, not only, to play an important role in providing most of the heating, cooling and electricity needs of rural people in Bangladesh as well as in the world, but also to solve global environmental problems.

Solar energy has been traditionally used for crop and fish drying but for the last one-decade government, NGOs, private organizations have been conscious for promotion of solar energy use in the life of rural householders. Thus, it is essential for scientists and researchers to find out

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effective renewable energy technologies (RETs) in the field of solar energy. This paper reviews the solar insolation and RETs practicing in Bangladesh in terms of its implementation, research and development activities.

## 2. GLOBAL ENERGY AND ENVIRONMENTAL SCENE

Fossil fuels are the most important source of world's present primary energy supply. Fossil fuels reserves are, however, diminishing rapidly across the world, intensifying the stress on existing reserves day-by-day due to increased demand. Fossil fuels, presently contributing to 80% of world primary energy, are inflicting enormous impacts on the environment. Climatic changes driven by human activities, in particular the production of Greenhouse Gas emissions (GHG), directly impact the environment. According to World Health Organization (WHO) as many as 160,000 people die each year from the side effects of climate change and the numbers could almost double by 2020. These side effects range from malaria to malnutrition and diarrhea that follow in the wake of floods, droughts and warmer temperatures. Another example of the severe impact caused by the global warming is the heat wave that hit across the Europe in summer of 2003 causing deaths in tens of thousands [1]. Climate change is responsible for huge economical consequences. Between the 1960s and the 1990s, the number of significant natural catastrophes such as floods and storms rose nine-fold, and the associated economic losses rose by a factor of nine. Figures indicate that the economical losses as a direct result of natural catastrophes over 5 years between 1954 and 1959 were US$35 billion while between 1995 and 1999 these losses were around US$340 billion [2]. Europe's extreme summer heat wave was the biggest single event in the year 2003 — costing more than $10 billion in agricultural losses alone and killing some 20,000 people [3].

Energy sector has a key role in this regard since energy during its production, distribution and consumption is responsible for producing environmentally harmful substances. A secure and accessible supply of energy is thus very crucial for the sustainability of modern societies. There is an urgent need for a quicker switch over of energy systems from conventional to renewables that are sustainable and can meet the present and projected world energy demand.

## 3. ENERGY CONSUMPTION AND PROJECTED DEMAND OF BANGLADESH

Bangladesh like other developing countries is energy deficient—the demand for primary energy in Bangladesh has increased considerably over the last decades and the country is facing serious energy shortage problems. Bangladesh's per capita energy consumption is very low, the lowest within the Indian subcontinent. The 2004 energy consumption value stands 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. 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%. About 77% of the country's population lives in rural areas, meting most of their energy needs (for domestic, commercial, and industrial needs) from traditional biomass fuels. Around 32% have access to electricity, while in rural areas the availability of electricity is only 22%. But the quality of power services in rural areas is very poor; there are reports of frequent voltage fluctuations, unreliable and erratic supply. Only 3 to 4% of the households have connection of natural gas for cooking purposes. Only about 2 to 3% households use kerosene for the same purpose and the rest (over 90%) of people depend on biomass for their energy needs [4].

Table 1 shows the final commercial energy consumption for the year 2000-2004. Traditional biomass fuel consists of agricultural residues, wood and wood wastes, and animal dung, and their shares in energy supply are approximately 46%, 34% and 20% respectively. It is the predominant fuel for rural cooking. Rural industries also consume a large amount of biomass. A rural activity that consumes a significant amount of biomass is paddy parboiling. Brick manufacturing also consumes a large amount of biomass fuels.

**Table 1. Bangladesh's Energy Consumption by Sector (Thousand Tons of Coal Equivalent)**

| Source | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|
| Domestic | 3740 | 4203 | 4655 | 5469 | 5826 |
| Industrial | 3326 | 3338 | 3459 | 3523 | 3286 |
| Commercial | 224 | 249 | 262 | 289 | 317 |
| Transport | 5517 | 6579 | 7205 | 7738 | 7921 |
| Agriculture and others | 1999 | 2347 | 2428 | 3437 | 4160 |
| Non-energy (fertilizer) | 9374 | 10338 | 10396 | 11089 | 11906 |
| Total | 24180 | 27054 | 28405 | 31545 | 33416 |

In the foreseeable future because of shortage of land there are dim prospects of increasing the supply of biomass fuels. On the other hand it is not economically possible to substitute all the biomass fuels by commercial fuels. On environmental considerations there is a need to maintain the supply of biomass fuels within the regenerative limits, and the demand for biomass fuels in excess of sustainable limits should be met by commercial fuels.

In fact, oil and coal are used only in activities where it is not convenient to use natural gas, such as the transport and agriculture sectors. As can be seen more than 40% of oil consumed is used in the transport sector. The small amount of oil used in the power sector can be attributed to the western part of the country having no gas. The highly unreliable power supply forces many industrial units to generate their own electricity during outages. In areas not served by gas pipelines, oil is used for this purpose. A large amount of oil is used for running irrigation pumps. The high consumption of oil in the residential sector consists of kerosene used for lighting. This highlights the

fact that a large portion of Bangladesh is not electrified. 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. The main use of coal is in the brick manufacturing industry. A small amount of coal is used in rural and semi-rural cooking and industries [5].

Two economic growth scenarios (low scenario and reference scenario) have been considered [6] for the period 1990 to 2020 to forecast future energy demand, as shown in Table 2, where the gross commercial energy consumption in 1990 is seen to be 256 PJ. From the Table it is observed that under the low scenario, with the increasing demand for energy, the requirement of imported commercial fuels will increase from 100 PJ in the year 2000 to 1638 PJ in 2020. The indigenous supply (natural gas, LNG and LPG, oil, coal, peat, hydroelectricity) of energy will remain almost static from 2000 to 2020. In order to reduce the gap between the projected demand and indigenous supply, the country will have to explore new avenues seriously.

**Table 2. Demand Supply Balance of Current Option (in PJ)**

| Time frame | Low scenario | Reference scenario | Indigenous supply |
|---|---|---|---|
| 1990 | 256.0 | 256.0 | 181.83 |
| 1995 | 342.0 | 362.0 | 276.71 |
| 2000 | 512.0 | 531.0 | 412.53 |
| 2005 | 769.0 | 827.0 | 412.6 |
| 2010 | 1025.0 | 1314.0 | 412.51 |
| 2015 | 1537.0 | 1979.0 | 412.51 |
| 2020 | 2050.0 | 3055.0 | 412.51 |

A balance between demand and supply of energy may be sought at individual level, household level, community level, district level, division level, country level, regional level and global level. Energy security is a multidimensional problem. Spatial (geographical), socio-economic and temporal (time) factors should be considered to achieve the objectives of the National Energy Policy. Simultaneous attention must be paid to solving the immediate crisis as well as to solving energy problems of the country in the short-, medium-, and long-term perspectives [5].

## 4. ENERGY RESOURCES OF THE COUNTRY

Natural gas is currently the main indigenous non-renewable energy resources of the country, which is being produced and consumed in significant quantities since 1970. Gas, the main sources of commercial energy, plays a vital role towards the growth of the economy of Bangladesh. The gas market is dominated by power and fertilizer (using gas as feedstock) sectors, which account for 46.65% and 21.71% of the demand. Composition of the country's natural gas (more than 90% Methane) has been particularly suited for power and fertilizer sector. Government is following a persistent policy to reduce dependence on imported oil and increase the use of indigenous natural gas in meeting the total energy demand of the country. Sector wise consumption of natural gas is given in Table 2 [7].

**Table 3. Sector Wise Consumption (in Percentage of Total Consumption) of Natural Gas**

| Sector | 1998 | 2000 | 2002 | 2004 |
|---|---|---|---|---|
| Electricity | 46.53 | 46.97 | 51.00 | 46.65 |
| Fertilizer | 30.14 | 27.38 | 21.62 | 21.71 |
| Industrial | 12.10 | 13.31 | 14.66 | 10.84 |
| Commercial | 1.30 | 1.24 | 1.17 | 1.12 |
| Cooking | 9.50 | 9.54 | 10.09 | 11.52 |
| Others | 0.43 | 1.54 | 1.46 | 8.16 |
| Total (MMCM) | 7514 | 8780 | 10324 | 12105 |

The cumulative efforts of exploration for oil and gas resources in Bangladesh has resulted in the discovery of 22 gas fields of various sizes, having a total gas initially in place (GIIP) of 28.415 TCF, and initial recoverable reserve of 20.509 TCF. Out of this, about 5.547 TCF has been produced and 14.962 TCF remains up to June 2004.

Currently, the country have only one coal mine operation project at Barapukuria in Dinajpur district. The project has a target to provide 1.0 million tones of coal per annum from the Barapukuria coalfield. It is planned that 85% of its annual production will be utilized to produce electricity; the rest will be used as fuel for brick making and other purposes. In the fiscal year 2004 to 2005, 74767.78 metric tons coal has been sold from the field for brick burning. The mining operations may continue up to 70 years from its inception. Bangladesh also has two other coal fields: 1000 million tons at Jamalganj and 450 million tons at Khalaspur. Early estimations suggest that it will not be techno-economically feasible to extract coal from Jamalganj reserve. The country has about 170 million tons of peat reserve in its southern regions. However, recoverable reserve is yet to be determined and the energy resources are not likely to be tapped in near future.

The country use to harness 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 government is contemplating to enhance the capacity of the reservoir and the plant and to produce more power, the feasibility of the enhancement project is underway. In addition, there are two other potential sites from where another 500GWh/annum of hydroelectricity can be produced. Given the locations, their respective hydro-geological set up, socio-economic, cultural, and environmental considerations, it seems highly unlikely that those potentials could be realized in near future.

## 5. POWER SECTOR OF THE COUNTRY

The utility responsible for generation of electricity throughout the country is Bangladesh Power Development Board (BPDB). It is established in 1972, is responsible for planning, construction and operation of power generation and transmission facilities throughout Bangladesh and for

distribution in urban areas except Dhaka and its adjoining areas. Rural Electrification Board (REB) is responsible for distributing electricity in rural Bangladesh. The Bangladesh Rural Electrification Program was founded with a Presidential Ordinance in October 1977 that established the REB as the semi-autonomous government agency reporting to the Ministry of Power Energy and Minerals Resources. Since its inception, the purpose of the program has been to use electricity as a means of creating opportunities for improving agricultural production and enhancing socio-economic development in rural areas, whereby there would be improvements in the standard of living and quality of life for the rural people. Dhaka Electric Supply Authority (DESA) and Dhaka Electric Supply Company Ltd. (DESCO) perform distribution of electricity in Dhaka and its adjoining areas.

Up to December 2005 the total installed power plants of the country (BPBD is the whole authority) was 4995 MW including 302 MW generated by Independent Power Producers (IPPs). Of the total installed power plants, the effective operational capacity was 4174 MW against the peak demand of about 4100 MW. The maximum generation was 3651.20MW on 22 December 2005. BPDB generates electricity from both the renewable (hydro) and non-renewable sources (natural gas, furnace oil, diesel etc.). There are some places where solar photovoltaic is used for supplying electricity to lighting and communication equipment. But the present coverage is as low as 16%. Electricity has been generating from natural gas since 1970 and from the last two decades it's share being dominate. Generation of electricity from natural gas was 88.44% of total generation by December 2005. Electricity generation scenario by fuel type is presented in table 3 [8].

## 6. GOVERNMENT POLICY FOR ENERGY

Energy development appears to be a major constraint for continued development of a LDC such as Bangladesh. The major stumbling block is lack in terms of capital investment since energy development programs are highly capital intensive. Traditionally these programs have been implemented with support from the donors and/or multilateral banks. Since independence the government has given adequate priority and about 20% of total public sector investment has been allocated for the development of energy sector. Even then the achievements made in this sector have not been able to cope with the growing demand for energy services, in terms of both quality and quantity.

In response to non-cooperation for large-scale investment in energy development by the major donors, which was fuelled by unacceptably high level of 'system loss' by the major government managed energy utility companies, the government encouraged participation of the private sector in energy development and management program. This was highlighted in the first ever National Energy Policy (NEP), completed and gazetted in 1996 [9]. The NEP recognized that energy plays important roles for socioeconomic development of the country and energy development and management should be brought under an integrated policy framework. The NEP set a number of objectives, which are outlined below:

- To provide energy for sustainable economic growth so that the economic development activities of different sectors are not constrained due to shortage of energy.
- To meet the energy needs of different zones of the country and socio-economic groups.
- To ensure optimum development of all the indigenous energy sources.
- To ensure sustainable operation of the energy utilities.
- To ensure rational use of total energy sources.
- To ensure environmentally sound sustainable energy development programs causing minimum damage to environment.
- To encourage public and private sector participation in the development and management of the energy sector.

**Table 4. Electricity Generation Scenario by Fuel Type (as on 22 December 2005)**

| Fuel type | Installation Capacity | | Effective operational capacity | | Maximum generation | |
|---|---|---|---|---|---|---|
| | MW | % | MW | % | MW | % |
| Natural gas | 4271 | 85.51 | 3666 | 87.83 | 3229 | 88.44 |
| Furnace oil | 342 | 6.85 | 283 | 6.78 | 211 | 5.78 |
| Hydro | 230 | 4.60 | 130 | 3.11 | 120 | 3.28 |
| Diesel | 151.85 | 3.04 | 95 | 2.28 | 91.20 | 2.50 |
| Total | 4995 | 100 | 4174 | 100 | 3651.20 | 100 |

"National Energy Policy (NEP), 1995" of Bangladesh has got guidelines for Renewable Energy Technologies. Government has also adopted "Private Power Generation Policy, 1996" for encouraging private sector participation in the electricity generation sector of the country along with BPDB and already several IPPs are supplying electricity to the national grid. Apart from this, another policy – "Small Power Generation Policy, 1998" has also been introduced to encourage small electricity generation capacity up to 10 MW throughout the country by the private sector. There is no national coordinating agency for renewable energy sector in Bangladesh. At present, Power cell is entrusted by the Ministry of Energy and Mineral Resources (MEMR) to foster development of RETs in Bangladesh. A "Draft Renewable Energy Policy" [10] has been submitted by the Power Cell of MEMR which is yet to be approved by the Government of Bangladesh (GOB). Besides, Establishment of Renewable Energy Development Agency (REDA) has been proposed by the NEP, 1995 of GOB. In 1998, The Government of Bangladesh lifted import duty and Value Added Tax (VAT) from solar PV. Solar PV program of different government bodies (BPDB, LGED, REB) are basically subsidy driven.

## 7. SOLAR INSOLATION IN BANGLADESH

Bangladesh is situated between 20°34′ to 26°38′ degrees north latitude and 88°01′ to 92°41′ degrees east, which is an ideal location for solar energy utilization. Daily average

solar radiation varies between 4 to 6.5 kWh/m$^2$. Maximum amount of radiation is available on the month of March to April and minimum on December to January. Different R&D 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 which has got long-term measured data of Dhaka city in Bangladesh. The published data are average of results of hourly measurements of over three years global and diffuse radiation with Eppley Precision Pyranometer.
- Bangladesh Meteorological Department has 34 sunshine recording stations situated generally in towns and cities.
- Department of Mechanical Engineering, Bangladesh University of Engineering and Technology, has also got time series data of Dhaka city.

**Table 5. Monthly Average Global Solar Insolation (in kWh/m$^2$/Day) at Different Cities of Bangladesh**

| Months | Dhaka | Rajshahi | Sylhet | Bogra | Barisal | Jessore |
|---|---|---|---|---|---|---|
| Jan | 4.03 | 3.96 | 4.00 | 4.01 | 4.17 | 4.25 |
| Feb | 4.78 | 4.47 | 4.63 | 4.69 | 4.81 | 4.85 |
| Mar | 5.33 | 5.88 | 5.20 | 5.68 | 5.30 | 4.50 |
| Apr | 5.71 | 6.24 | 5.24 | 5.87 | 5.94 | 6.23 |
| May | 5.71 | 6.17 | 5.37 | 6.02 | 5.75 | 6.09 |
| Jun | 4.80 | 5.25 | 4.53 | 5.26 | 4.39 | 5.12 |
| Jul | 4.41 | 4.79 | 4.14 | 4.34 | 4.20 | 4.81 |
| Aug | 4.82 | 5.16 | 4.56 | 4.84 | 4.42 | 4.93 |
| Sep | 4.41 | 4.96 | 4.07 | 4.67 | 4.48 | 4.57 |
| Oct | 4.61 | 4.88 | 4.61 | 4.65 | 4.71 | 4.68 |
| Nov | 4.27 | 4.42 | 4.32 | 4.35 | 4.35 | 4.24 |
| Dec | 3.92 | 3.82 | 3.85 | 3.87 | 3.95 | 3.97 |
| Avg. | 4.73 | 5.00 | 4.54 | 4.85 | 4.71 | 4.85 |

Recording period: 1988-1998.

**Table 6. Daily Average Bright Sunshine Hour at Dhaka City**

| Month | Daily mean | Maximum | Minimum |
|---|---|---|---|
| January | 8.7 | 9.9 | 7.5 |
| February | 9.1 | 10.7 | 7.7 |
| March | 8.8 | 10.1 | 7.5 |
| April | 8.9 | 10.2 | 7.8 |
| May | 8.2 | 9.7 | 5.7 |
| June | 4.9 | 7.3 | 3.8 |
| July | 5.1 | 6.7 | 2.6 |
| August | 5.8 | 7.1 | 4.1 |
| September | 6.0 | 8.5 | 4.8 |
| October | 7.6 | 9.2 | 6.5 |
| November | 8.6 | 9.9 | 7.0 |
| December | 8.9 | 10.2 | 7.4 |
| Average | 7.55 | 9.13 | 6.03 |

Recording period: 1961-1980.

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 table 5 [11] and 6 [12] respectively.

## 8. RENEWABLE ENERGY TECHNOLOGIES (RETS) PRACTICE FOR SOLAR ENERGY

### *Solar Photovoltaic*

The role of PV generated electricity for various applications ranging from water pumping, domestic supply, 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. The success of this technology in Asia is even more remarkable due to the fact that most homes are still not connected to the national grids [13].

The solar PV program was initiated in India in 1975 and during the Eighth Five Year Plan, (1992-1997) PV program has been allocated Rs 900 million (about 10% of the entire renewable energy budget). It has indigenously developed technology and production facilities. India is the second largest crystalline silicone manufacturer in the world with an annual manufacturing capacity of 8.5 MW. In India, there are total 50 companies involved in PV. The telecommunications sector of the government is the major user of PV with over 5.5 MW of purchases in 1995 [13]. Up to March 2006, cumulative achievement of India in solar PV systems are: PV power 2.74 MW, PV pumps 6818, PV street light 54795, Solar Home Systems (SHSs) 0.342 million and solar lantern 0.56 million [14].

Despite of large potential of solar system in Bangladesh, utilization of solar energy has been limited to traditional uses such as crop and fish drying in the open sun. Solar PV are gaining acceptance for providing electricity to households and small businesses in rural areas. In 1988, Bangladesh Atomic Energy Commission (BAEC) installed several pilot PV systems. The first significant PV-based rural electrification program was the Norshingdi project initiated with financial support from France. Three Battery charging stations with a total capacity of 29.4 kWp and a number of stand alone Solar Home Systems (SHSs) with a total capacity of 32.58 kWp were installed. REB owned the systems and the users paid a monthly fee for the services. Since 1996, penetration of SHSs increased rapidly, mainly due to the efforts of Grameen Shakti, which sells PV systems on credit to rural households through its extensive network. Several other NGOs such as CMES and BRAC are also engaged in promoting PV technology. PV modules are generally imported, while there are a few private companies manufacturing PV accessories [15].

According to a World Bank funded market survey, there is an existing market size of 0.5 million households for SHSs on a fee-for-service basis in the off grid areas of Bangladesh. This assessment is based on current expenditure levels on fuel for lighting and battery charging being substituted by SHSs. Also it has been observed that in most developing countries, households typically spend not more than 5%

of their income on lighting and use of small appliances. By this measure, about 4.8 million rural Bangladeshi households could pay for a solar home system [16].
At present the national grid is serving only 50% of the nearly 10,000 rural markets and commercial centers in the country, which are excellent market for centralized solar photovoltaic plants. Currently private diesel genset operators are serving in most of the off-grid rural markets and it has been found that 82% of them are also interested in marketing SHSs in surrounding areas if some sorts of favorable financing arrangements are available [17]. Summary of installation of solar PV systems by different organizations in Bangladesh is shown in Table 7.

### *Solar Thermal Technologies*

The solar thermal technologies that are of interest in Asia are solar hot water systems, solar dryers and solar cookers. Many countries in the region have developed domestic solar water heaters (DSWHs) and sell them commercially, while even Australian, European and American models are also available in a few countries. The DSWHs are usually the thermosyphon type with a collector area of about 2 $m^2$ and a storage tank of about 200 litres. Some countries have a strong program in this technology with government-aided incentives and other financial aids promoting the growth of this technology [13].

In India, solar water heater of about one million $m^2$ of collector area have been installed [14]. There are around 61 units of solar dryers and 10,000 units of solar desalination systems. By the end of March 2006, 55 small manufacturers of solar cookers have sold around 575,000 units. An Integrated Solar Combined Cycle Power Plant (140 MW) with a Solar Power Generating System of 35 MW is in the inception stage of development in Rajasthan [18]. Fiscal incentives like exemption of customs duty, central sales tax and depreciation under income tax are provided, while the monetary incentive of Rs 1000 per $m^2$ of collector area is also given.

Although R&D activities show viability of solar thermal devices, these have not found applications in the public or private sector. While solar water heaters for hotels and hospitals could bring down electrical loads, solar cookers should conserve biomass and solar dryers would be useful for drying timber, paddy, fruits and vegetables with benign environmental effects.

Only BRAC has propagated this technology in the field by installing 260 Hot Box cookers. The NGO has a future plan to install more 5,000 Hot Box cookers allover the country. Some of the organizations of the country (in Table 8) have been continuing R&D activities in the field of solar thermal technologies. Suitable incentives are essential to make such applications attractive. Suitable policies and mechanisms are yet to be developed for increasing efficiency of every use in different sectors.

**Table 7. Summary of Installation of Solar PV Systems by Different Organizations**

| Name of organizations | Number installions & locations | Capacity (kWp) |
|---|---|---|
| **Government organization** | | |
| Local Government Engineering Department (LGED) | A number of SHSs in coastal cyclone shelters in coastal districts | 19.6 |
| | 1 SHS in Tribal community center at Khagrachari and 1PV water pump in Prantik lake at Bandarban | 0.45 |
| | 151 SHSs, 9 centralized units, and 1 water pump in remote off-grid areas allover the country | 33.8 |
| **Semi-Government/Autonomous organizations** | | |
| Bangladesh Council of Scientific and Industrial Research (BCSIR) | 16 SHSs, 1 pump, 2 solar data logging units (only for research). | 1.5 |
| Bangladesh Power Development Board (BPDB) | 300 SHSs, and 4 centralized units at Juraichari, Rangamati | 54 |
| Rural Electrification Board (REB) | 1272 SHSs allover the country | 72.75 |
| **Non-Governments organizations** | | |
| Grameen Shakti | 42,119 SHSs all over the country | 2151.02 |
| Bangladesh Rural Advancement Committee (BRAC) | 10,456 SHSs all over the country | 300.545 |
| Thangamara Mohila Sobuj Shangha (TMSS) | 762 SHLSs | 42.80 |
| Center for Mass Education in Science (CMES) | 796 SHLSs | 39.80 |
| ANANDO | 35 SHLSs | 3.75 |
| Coast Trust | 532 SHLSs | 26.60 |
| Integrated Development Foundation | 601 SHLSs | 30.05 |
| Srizony Bangladesh | 1710 SHLSs | 85.50 |
| SHUBASHATI | 592 SHLSs | 29.60 |
| **Private companies** | | |
| Singer Bangladesh Ltd. | 31 SHLSs | 1.55 |
| SIEMENS Bangladesh Ltd. | 1000 SHLSs and 5 centralized units | 51.26 |
| Micro Electronics Ltd. | 700 SHSs | 39.31 |
| First Bangladesh Technologies Ltd. (FBT) | 93 SHSs | 4.035 |
| Bangladesh Center for Advanced Studies (BCAS) | 5 Solar Health Care | 2.265 |
| UBOMUS | 400 SHSs | 20 |
| Total = 61567 SHSs/SHLSs, 18 Centralized units, 5 Solar health center, Solar costal cyclone shelters and 3 water pumps | | 3.01 MW |

## 9. RESEARCH AND DEVELOPMENT ACTIVITIES IN THE FIELD OF SOLAR ENERGY

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 the field of solar energy technologies have been carrying out in these Universities, research centers and in some NGOs. These are summarized in table 8 [19].

## 10. ORGANIZATIONS AND THEIR ACTIVITIES FOR DEVELOPMENT OF RETS FOR SOLAR ENERGY

Summary of the several attempts by some of the government organizations, NGOs and international organizations for overall development of the solar energy technologies are presented in the subsequent sections.

***Projects by Government Organizations***

***i) Cyclone shelter solar electrification project of LGED***

The LGED is playing a pivotal role in rural infrastructure development. People at large in rural Bangladesh are now enjoying the benefits of LGED's different rural development projects. Rural infrastructure development projects undertaken by LGED are contributing a great deal towards the socio-economic development in the country along with the development of communication and market networks. Various activities under different projects have been creating short and long term employment opportunities for the poverty-stricken people.

Through JICA assisted cyclone shelter project, LGED has installed 19.65 kWp (17.01kWp for SHSs and 2.64 kWp for street light) of solar PV systems in several cyclone shelters in coastal districts of Bangladesh. In each of the cyclone shelters, the solar installations have been designed to operate 18 lamps and one TV.

***ii) Chittagong hill tracts solar electrification project of BPDB***

Engineers of BPDB have conducted a "Feasibility Study for Solar PV in Chittagong Hill Tracts Region" and currently implementing Solar Photovoltaic Project at three upazilas in the Chittagong Hill Tracts region where different types of solar photovoltaic applications including solar home systems, water pumps, vaccine refrigerators, street lamps, centralize power station etc. Up to January 2005, BPDB installed solar PV systems of total capacity 54 kWp at Juraichari upazila: 10.8 kWp for centralized system and 7.2 kWp for street light and rest 36 kWp for 300 SHSs (ranging 75 to 120Wp). Another two remote upazila Beliachari and Barkol will also be under solar electrification by providing 1800 SHSs. BPDB expected to installed of total capacity around 150 kWp in Chittagong Hill Tracts Region. The overall charge of supervision and bill collection of different systems will be done by the Beneficiary Management Committee composed by the local people [8].

**Table 8. Summary of R&D Activities in the Field of Solar Energy Technologies in Bangladesh**

| RETs | Organizations | Activities |
|---|---|---|
| Solar PV | Garmeen Shakti, RUET, CMES, IFRD | Local manufacturing of all balance of system components (like Charge Controller, Cable, Inverter, Converter etc.) possible. Solar PV demonstration has been carrying out in Rajshahi University of Engineering & Technology (RUET) and in Institute of Fuel Research and Development (IFRD). |
| Solar water heaters | RERC, IFRD and CMES, RUET | Manufacturing with local design and fabrication facility possible. |
| Solar cooker - parabolic | IFRD and ANANDO | Institute of Forest Research and Development (IFRD) has successfully field-tested its design which can quickly boil water on clear sunny days. Such solar cookers are now on sale at a cost of TK580.00 (US$ 9.00) at IFRD. ANANDO is also manufacturing and marketing it's products with imported materials and design. |
| Solar cooker – box type | IFRD and CMES | IFRD's design is made of locally available raw materials. The manufacturing costs of such a cooker is about TK 1000 (US$ 16.00) excluding the cost of utensils. The cookers are now being sold at IFRD. |
| Solar dryer | IFRD, BRRI and BAU | Different types have been designed and tested with locally available materials |
| Solar wood seasoning plant | BFRI | A simple, inexpensive and effective solar kiln has been developed for seasoning timber using solar radiation. The kiln can be constructed conveniently with locally available materials. Timbers of different species and dimensions can be seasoned throughout the year in the solar kiln. |
| Solar passive architecture | BCSIR | A solar house has been designed and built in the BCSIR campus, the purpose is to keep the house warm in winter and cool in summer. |

***iii) Renewable energy technologies projects of REB***

**"Diffusion of renewable energy technologies" project by REB:** Under the first phase of the project (1993/94-1997/98), a "Renewable Energy" cell of REB has implemented the first semi-commercial 62 kWp Solar Photovoltaic Project and installed 5 SHSs (ranging 50 to 92 Wp) of capacity 370 Wp. In the second phase of the project (2002/03-2005/06), REB has been able to install 605 SHSs (ranging 50 to 100 Wp) a total of capacity 36.11kWp allover the country by February 2006 [20].

**Rural electrification through solar energy (IDA) project of REB:** The project has been taken up by REB in the FY 2002/03 and it will be continued up to FY 2006/07. Under this project, REB has already installed 662 SHSs (ranging 36-92 Wp) a total of capacity 36.27 kWp allover the country by February 2006 [20].

***iv) Feasibility study on R&D on RETs by IFRD***

The IFRD launched its journey as the fuel research division of the East Regional Laboratory, Dhaka in 1954. After the independence of the country it was renamed as Fuel Division of BCSIR Laboratories, Dhaka. IFRD was established as a separate institute of BCSIR in 1980. The objectives of the institute are:

- To develop the RETs for utilizing the existing traditional and commercial fuels more efficiently
- To assess the rapid production of biomass and fast growing trees for its utilization as fuel
- To find better utilization of biomass and other organic wastes for production of biogas and its utilization for generation of electricity
- To develop RETs for utilization of solar, wind and hydropower
- To produce different petrochemicals from natural gas
- To study the environmental pollution caused by the emission from automobiles and industries

Recently a project on the "Feasibility Study on R&D of Renewable Energy (Solar, Wind, Micro-Mini Hydro)" has been undertaken by the IFRD of BCSIR. The aim of the project is to generate data and information to study the possibility of natural solar, wind and micro hydro power applications in Bangladesh either for water pumping or for generation of electricity particularly in remote and off-shore islands. The small industries may find solar, wind and micro hydropower prospective in remote rural areas or in the islands and coastal region. Acquired technical knowledge from this project will be helpful to develop new technologies in the field of solar, wind and micro hydro, so that the quality of life of the people of coastal, off-shore islands, hilly and other remote rural areas can be improved significantly. IFRD has established a laboratory for conducting research and testing on solar, wind and micro-hydro equipment. Solar energy component of the program have been collected solar data (insolation, temperature and humidity) for three: Dhaka, Tecknaf and Sailo propat in Bandarban district.

***Projects by Private Companies and NGOs***

***i) Solar energy programs of Grameen Shakti***

Grameen Shakti was established in 1996 to develop and popularize renewable energy resources. GS has been appreciated globally for it's outstanding approach of "micro-credit" for delivering solar home systems in rural areas. GS expects not only to supply renewable energy services, but also to create employment and income-generation opportunities in rural Bangladesh. GS has got loan and grant from different bilateral and multilateral development partners including GEF, IFC, USAID, SIDA etc. [15].

Up to June 2005 Grameen Shakti has installed 42,119 SHSs in 14 districts of Bangladesh. Over the next two years, Grameen Shakti intends to install 20 small battery-charging stations, 20 computer training centers and 20 multi-service centers, all powered by solar energy [15].

***ii) Dissemination program of CMES***

The CMES was created in 1978 with an aim to take science and technology to the common people of the country. Later on CMES started solar energy related activities in the distant areas of the country through its field offices. It has carried R&D activities on solar cookers, solar water heaters, solar dryers, solar home systems etc. It has recently established its "Solar Lab" to take up adaptive research on accessories of solar PV systems, such as tube light ballasts, charge controllers, inverters, income generating appliances like sewing machines, drilling machines etc. It has installed 796 SHSs under Rural Electrification and Renewable Energy Development Project (REREDP) of IDCOL. At present, CMES is one of the country's focal agencies in the "RETs in Asia Program" [21].

***iii) Renewable energy program of BRAC***

BRAC was established as a relief organization in 1972 after liberation war. It has evolved into country's largest NGO with its objectives of "Alleviation of Poverty and Employment of Poor". Its wide range of programs and projects in areas including education, health care, agriculture, poultry, craft, dairy and micro credit banking are dispersed throughout the country. BRAC started it's Renewable Energy Program for overall development of RETs in remote locations [22]. Under this program BRAC has installed 10,456 SHSs by May 2005 and 260 Hot Box cookers. It has also installed 2 grid-interactive PV systems and 6 PV-Wind hybrid systems. The program involved installing PV systems in its branch offices (training centers, schools, health clinics) and micro-enterprise projects (carpentry, tailoring shop, cloth dyeing, etc.) and in government-owned buildings (rest houses, cyclone shelters, weather-monitoring stations). BRAC has a future plan to install 100,000 SHSs, 5,000 Hot Box cookers and a solar energy research institute [22].

***Bilateral and Multilateral Development Partner Assisted Projects***

***i) Sustainable rural energy (SRE) project of LGED***

The SRE has been conceived by LGED, a component of Sustainable Environment Management Program (SEMP), a project of Ministry of Environment and Forest funded by UNDP. The twin objectives of SRE component under SEMP are technology demonstration and technology transfer in the field of renewable energy in Bangladesh.

The overall objectives of SRE are to explore opportunities for community based renewable energy options for different applications and its multipurpose use in off-grid areas of Bangladesh. Component activities of SRE are grouped into three major categories:

- Demonstration of diversified applications of renewable

energy technologies.
- Capacity building through training on renewable energy technologies.
- Development of Renewable Energy Information Network (REIN) in Bangladesh.

Considering the natural resource base and socio-economic condition, the SRE project has also considered solar energy with other three potential renewable energy sources in Bangladesh: biomass, wind and micro-hydro. Under this project LGED has installed 151 SHSs, 9 centralized PV systems and 1 PV water pumping unit of a total capacity 33.80 kWp [12].

As one of the objectives of SRE project, LGED has also developed the "Renewable Energy Information Network (REIN)", with a comprehensive scope for developing an information platform for RETs. This network will be designed and tailored to facilitate the energy planners, project developers, researchers and all relevant organizations in developing RET projects and promotion of renewable energy utilization in Bangladesh [12].

**ii) *"Opportunity for women in renewable energy technology utilization in Bangladesh" project by PSL***

This pioneering project was initiated in September 1999 with funding from ESMAP as an effort towards demonstrating the capability of rural women from developing countries in engaging as clean energy service providers for their community. Rural women are already the largest users of renewable energy, by virtue of using biomass fuel for cooking, yet their role in modern energy utilization is usually overlooked. This project was designed with a vision that allows the role of rural women to be enhanced by extending their participation in technology based activities. The project location is Char Montaz, an island with 2000 households, in the southern coastal region of Golachipa Thana of Bangladesh. 35 rural women of Char Montaz are engaged in the operation of a micro-enterprise for construction and sale of DC lamps, which can be used in combination with batteries in Solar Home Systems (SHSs). With continued training from this project, the women learnt lamp construction with quality control, business development and marketing. More than 1000 lamps are being used with re-chargeable batteries for lighting the rural houses, shops, mosques and fishing boats. As a significant contribution, this activity has removed some of the social and cultural discrimination associated with the gender role to be played by women, an opportunity aimed towards poverty alleviation. Overall impact to be achieved from this project has far-reaching potential not limited to the direct participants only, since the benefit of improved environment extends with every new household that adopts modern lighting. The project has entered its second Phase in 2002 where the objective is to:
- Expand the scope of income generation for women. In addition to on-going DC lamp assembly, enhance the manufacturing capacity to assemble state-of-the-art charge controllers for solar home systems for the upcoming national projects.
- Expand the market for off-grid DC lamp and battery service to a larger area so that more rural people can experience the benefit of modern lighting.
- Demonstrate financial viability of solar electrification service for dispersed households that are too distant for grid and micro-grid alternatives.

***iii) Solar and wind energy resource assessment (SWERA) project***

In most of the developing countries, renewable resource information is absent or inadequate. This is one of the major barriers for widespread deployment of RETs in these countries. Understanding this obstacle, UNEP is carrying out a 3-year (June 2001 to July 2004) long "Solar and Wind Energy Resource Assessment (SWERA)" project with GEF fund. SWERA will start with the following countries - China, Bangladesh, Sri Lanka, Nepal, Ghana, Kenya, Cuba, Honduras, El Salvador, Nicaragua, Algeria, Brazil and Guatemala. The overall goal of this project is to promote the integration of wind and solar alternatives in national and regional energy planning and sector restructuring as well as related policymaking. The project will enable informed decision-making and enhance the ability of participating governments to attract increased investor interest in renewable energy [23].

Under the SWERA Project, High resolution (approx. 0.05° to 0.15°, 1 to 3 hourly) site/time specific solar resource datasets will be derived from geostationary satellite-INSAT and METEOSAT5. It is expected that since INSAT has higher spatial resolution and METEOSAT has higher time resolution the combination will give the best product. Maps and GIS data sets of monthly and yearly sums of Global Radiation and of Direct Radiation covering the land areas of Bangladesh will be made available with an expected accuracy of better than 10% with respect to the annual sum of solar radiation. The maps will be based on 3 years of time series data with a time resolution of 1 hour. Bangladesh will have:
- Access to enhanced solar resource maps and expanded databases including national validation results and expanded time series information
- The capacity to use the data in an effective manner to facilitate solar technology investment
- Understanding of how the resource data are developed
- Improved ability to undertake measurement programs for further validation data
- Site-specific pre-feasibility studies

***iv) Rural electrification and renewable energy development project (REREDP)***

The blended IDA/GEF Bangladesh Rural Electrification and Renewable Energy Development Project supports the Government's development strategy to increase rural electricity access, and thereby promote social development and economic growth. This objective is sought to be achieved in the following four ways:
- Assisting the REB to expand and intensify rural grids, improve the operational and financial performance of the rural co-operatives (known as PBSs), and reduce power outages in the ural grid systems

- Facilitating development of decentralized, mini-grids, based on natural gas, diesel, wind and hydro sources where feasible
- Promoting use of solar home systems in rural areas inappropriate for grid expansion
- Increasing productive use of electricity and enhancing poverty impacts.

The project defines the institutional models, the stakeholders and implementing agencies, and financing and implementation details developed to place the renewables component within the context of a larger rural electrification strategy for Bangladesh. The blend IDA/GEF project will support this strategy, and a part of the IDA credit will be employed to promote large-scale application of renewables with investment and technical assistance resources [12].

**Establishment of a SHS based pre-electrification program for PBSs:** The project will enable REB and five PBSs to develop a 'fee-for-service' SHSs market and install 14,000 SHS in rural households on this basis. IDA and Government will provide credit resources, with GEF grants to finance the SHSs program. Besides investment funding, TA resources are to be provided to strengthen institutional capacity, develop a sustained 'fee-for-service' PV market, provide implementation support and training, establish arrangements to test and certify equipment, monitor project progress, establish and operate a socio-economic cell in REB to design, implement and evaluate programs to use electricity to increase rural incomes and social well being, and establish sound performance monitoring and evaluation methods.

**Establishment of a SHS credit line and TA to support private sector, NGOs and MFIs:** The project will specifically support capacity building of private sector, PBSs, NGOs and MFIs to enter into and implement solar development programs. Capacity building would include generating awareness about solar based opportunities, disseminating information widely and effectively, developing skills among 'institutions' and 'people' to implement and manage the program and training for solar technicians, community mobilizers and microfinance practitioners. The project envisages GEF financed TA, matched by IDA and Government, for market development and solar promotion. To overcome financing barriers, a renewable energy credit line from IDA resources and a GEF co-financing grant is proposed to be set-up and operated by the Infrastructure Development Company Limited (IDCOL) on commercial terms to finance 64,000 SHSs over a period January 2003 – June 2008. IDCOL will on-lend to MFIs (or NGOs as the case may be) and solar businesses to facilitate the purchase of solar home systems by consumers. Up to May 2005 ten participating organizations (BRAC, COAST Trust, CMES, GS, IDF, Srizony Bangladesh, Shubashati, TMSS, UBOMUS, Singer Bangladesh Ltd.) has installed 42699 SHSs allover the country.

**Promotion of renewable energy in selected rural areas of Bangladesh:** The main objective of the project is to test, promote and disseminate renewable energy in selected remote areas of Bangladesh. The project period is 3 years and estimated cost is DM 4 million which will be funded by GTZ of Germany. GTZ has selected Bangladesh Rural Electrification Board as the implementing agency of the project. To achieve the project objective, the following five project outputs have been proposed by GTZ :

- Support of establishing an institutional framework for coordination of renewable energy activities at national level and facilitating development of suitable strategies.
- Adaptation and promotion of appropriate technologies for productive use of renewables in small-scale enterprises.
- Private sector based marketing, production, maintenance and recycling systems for renewables.
- Sustainable access to renewable energy services for selected self-help groups and social service providers at community level (e.g. schools, rural health clinics, cyclone shelters).
- Strengthening of technical and management capacities of major implementing agencies.

## 11. DISCUSSIONS

Biomass and kerosene are the major sources of energy in rural areas. Promoting renewable energy sources for rural energy requirements in conjunction with alleviation of rural poverty, diversification of energy resources and reduction of oil imports are needed to shift the economical growth towards greater sustainability, as well as environmental and social stability. Information on the socio-economic aspects are limited. The available data are scattered and least quantified. So, it is difficult to assess full impact of renewable energy in the country both socio-economically and environmentally. In the subsequent sections, different socio-economic benefits of RETs: Bangladesh perspective are described briefly.

### *Reduction in Electricity Transmission and Distribution Cost*

There are more than 87,319 villages in Bangladesh, and most of them are unconnected to the national grid. It is estimated that only 22% of our rural householders are hooked on the grid. The electrification by grid extension or secondary power station can only reach a small minority of the population in rural areas. In view of the dispersion of localities and the low demand, the cost of production, transmission and especially distribution of electricity would be prohibitively expensive. Decentralized PV systems like stand-alone family lighting kit could effectively become a viable option in these areas. One of the essential features of the family lighting kit is its modularity, it can be tailored to the real needs of each consumer. Other advantages are:

- They do not require any grid lines to take the power to each house
- With no distribution and transmission lines losses are eliminated and theft of electricity is avoided.

### *Opportunity for Saving Foreign Currency*

Throughout the country, different government

administrative offices, NGO offices, health centers, schools, banks, police stations etc. are functioning. In the off-grid locations, these offices are either using traditional means (lantern, candles, kerosene wick lamps etc.) or operating their own diesel gensets. These offices have separate budgets for electricity and they can be easily served with solar PV applications. Bangladesh imports diesel with hard-earned foreign currency. It is obvious, that by substituting the diesel gensets with solar PV can diversify the energy mix and thereby save foreign currency. It is established fact that RETs can promote energy security and price stability by diversifying the energy supply. As RETs are modular, energy requirement can be met on-site very quickly and can be scaled up in the course of time with growing demand. Another problem associated with the conventional grid is line interruptions which in the case of RETs are much less and can be avoided if the user is trained properly.

***Improved Facilities for Social Activities***

The installation of solar PV technology in some rural localities of Bangladesh has brought significant changes in the awareness of people and also improved their quality of life. The initial reaction of the villagers was one of apathy and disinterest. However, when the community system became functional, the situation changed radically, people came in groups to watch TV. A large number of people from the neighboring villages were also attracted. The initial apathy first gave rise to curiosity and then to total acceptance and a feeling of pride. With lighting available, living habits improve. Leisure and entertainment from TV programs which were a short time ago a privilege of urban life could be routinely viewed by rural families. Public life was almost inexistent before street lighting were operational. Villages were seen teeming with life after darkness till late hours under the solar light. In the community centers, adult education programs, meeting of villagers and social gatherings were regular features.

***Creation of Better Environment for Rural Education***

Most of the rural off-grid schools don't have electricity. Solar PV can be used by these rural schools for different amenities. Modern benefits will not only attract more students, but will also retain quality teachers and staffs currently unwilling to be posted in the unelectrified areas. In the evening, the school facilities can be utilized for other social services like adult education, health education or recreational activities. Kerosene lanterns and candles provided inadequate lighting, cause pollution and entail fire hazard. PV lighting is more stable and brighter. With this good quality light, school children get better vision for their homework, with less or no strain, productive activities can also be carried out during the evening hours by housewives. PV systems provide also better lighting and at lower cost than dry-cell batteries. The dry-cell batteries not only are often of poor quality, but they can take a significant fraction of low income of a poor family. They have a short lifetime and there is no disposal.

***Employment Opportunity***

RETs are up to three times more employment-intensive than fossil fuel or nuclear power plants. This benefit can be easily seen from the global wind energy business. According to a survey by Danish wind energy manufacturers, 17 worker-years are created for every megawatt of wind turbine manufactured and five worker-years for every megawatt wind power installed. In the year 2000, the wind energy industry provided more than 85,000 jobs worldwide and could provide up to 1.8 million jobs by 2020. Electrification of microenterprises in the off-grid areas can increase income or create new job opportunities for the rural poor which has been observed from the experience of Grameen Shakti which is a leading NGO involved in the RETs sector.

***Improved Facilities for Rural Health Center***

At present, a large amount of population is deprived of proper health care due to absence of electricity in remote far-flung areas. Provision of health care in rural areas is a major concern, therefore rural health centers are integral parts of the primary health care systems in Bangladesh. However, their ability to deliver basic health services depends on the availability of electrical energy, particularly for vaccine storage, lighting and safe water. Family health, especially maternal and infant welfare, has been improved when health centers in rural areas were upgraded by providing them with solar PV energy. This has ensured, to some extent, the success of the immunization program.

Electrification helps family planning activities. An exhaustive analysis to find out the link between electrification and fertility in Bangladesh shows that the fertility rate among girls is 0.67 in electrified households and 1.17 in nonelectrified households.

***Solution of Drinking Water in Remote Islands***

After the installation of PV water pumping systems, water requirements for gardens, vegetables, cattle breeding and cash crops had yielded substantial gains to peasantry and had increased their income. Drinking water was also secured on long term basis. This is a major social benefit, as impure drinking water is responsible for a large fraction of infant mortality. The fact a storage tank is included in the solar water pumping system means reducing the drudgery of fetching water for women. Beside the costal area, there are several islands lacking in potable water for drinking. Using solar water desalination technology to tackle the water shortage problem has had a real impact on the standard of living within these islands.

***Development of Rural Women Life Style as Well as Safe Environment***

Provision of electricity has many effects which can benefit women. However, PV does not solve the urgent need of a satisfying energy source for cooking. Domestic

cooking is a major consumer of lignocellulosic biomass. Woman are solely involved in this activity. To collect tree biomass, women, sometimes assisted by children, spend several hours a day. Though, it is done free, releasing women from doing mundane work will empower them. Indeed, women will get more time for self-advantage: adult literacy, actualization about nutrition, family planning, skills training such as sewing, etc. thus better child care, gardening and hence increased revenue. This affects the nutrition and the health of the entire family.

Ecological and environmental impacts may be raised for the use of lignocellulosic biomass. The distribution of fragile forest resources has led to desertification and reduced agricultural productivity as a result of declining soil fertility, decreased groundwater recharge, loss of biodiversity and other micro-climate effects. Deforestation has a negative effect on both the environment and women's health, bringing in less income, necessitating more work and increasing the downward spiral of poverty. Education, especially of girls, suffers when fuel wood and water resources are scarce. Incomplete combustion of fuel wood from traditional stoves generates harmful air pollutation such as carbon monoxide, suspended particulates, sulphur oxides, nitrogen oxides and hydrocarbons which have been linked to eyes and respiratory diseases. Environmental degradation thus affects not only their ability to look after their family's nutrition and health, but also their own health, well-being and income generation activities. Introduction of renewable energy is the quickest way to initiate a program of social upliftment for the majority of people in rural areas. With the use of improved stoves, biogas or solar cooker women find a great relief at home as pollution is minimized. On a global level, burning wood releases carbon dioxide and other greenhouse gases which threaten a global warming.

## 12. CONCLUSIONS

Dissemination of solar energy throughout the country should be first priority in solving our energy crisis. There is no way other than taking solar energy for reducing environmental degradation. Scientists of the world are now seeking energy solution from the resource, which is highly available in the country. By producing energy from solar isolation from our abundance sources we can solve a big portion of energy deficiency. The energy sector of the world is evolving remarkably. It is facing an accelerating compound crisis of the globally established fossil (oil) and atomic energy system; therefore, immediate different breakthroughs for solar energy are necessity to reach our electricity goal. We are going to run out of gas in the next 25 years. Frequently escalating oil prices indicate the depletion of fossil resources and the urgent need to replace the current mix of fossil transport fuels.

The overall effect of community facilities such as school, health centers or water pumping can contribute significantly to welfare and rural development. And the tendency to emigrate from rural areas to urban cities has been stemmed, even a quantum leap in the quality of life has been raised. Above all, rural electrification is viewed as a mean of narrowing the gap between the life style in urban and rural areas. It can also be regarded as an extension of benefits deriving from national overall economic development to the rural folk. Lack of electricity will deprive enter populations of rural areas access to better living standards and will lead to social tensions and political instability.

In the last two decades, a lot of activities in the field of renewable energy have been taken to popularize modern RETs by different agencies and needed to be encouraged and continued. The Renewable Energy Programs of Grameen Shakti has become highly acclaimed among national and international policy makers, bilateral and multilateral development partners and by the RET enthusiasts. It is expected that the GEF funded "Rural Electrification and Renewable Energy Development Project" will also accelerate the growth of RETs utilization in the country.

RETs are slowly finding a niche market in Bangladesh. But still there are lots of barriers. However appropriate financing of this purchases is one of the key impediments to accelerate dissemination of renewable energy. In Bangladesh 44% people live in below poverty level and it is essential to create special subsidy for propagating RETs in their life. In addition careful attention should be paid to local customers, social hierarchy, discussion and technology training.

A gradual change from conventional energy to renewable energy would benefit both the economy and the nation as a whole.

Time-bound targets for mass dissemination of different renewable energy technology options have to be adopted by the Government of Bangladesh (GOB) for fulfilling its obligation of universal electrification program by the year 2020.

The draft Renewable Energy Policy, submitted by the Power Cell, should be approved by the GOB immediately and Renewable Energy Development Agency (REDA) should be created to act as a focal point in the renewable energy sector of Bangladesh. REDA should be dedicated to renewable energy promotion, by supporting comprehensive economic energy analysis encouraging household sector to use renewable instead of conventional energy, managing and administering credit funds and subsidies and also to remove the barriers prevailing in the renewable energy sector of the country. In other words, the overall objective of the REDA is to implement a national policy that will encompass the supply of adequate, reliable, sustainable and safe energy to all sectors of the national economy, by reducing our dependence on conventional energy and oil importation and consequently trade balance.

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