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Prospects of Renewable Energy and Energy Storage Systems in Bangladesh and Developing Economics

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I. Introduction

Bangladesh is situated in north-eastern part of south Asia and shares its longest border (4000 km) with neighbouring country India. Myanmar is the extreme southeast neighbour of Bangladesh and the Bay of Bengal is the southern boundary of it. With a land area of 147,570 km^2 and population of 162.20 million in 2011, Bangladesh is among the world's most densely populated nations (1099 people/km^2 in 2010) [1]. Bangladesh is one of the least urbanized nations with 72% people living in rural areas. Again, it is one of the poorest nations in the whole world with gross domestic Product (GDP) per capita of US $1,700 in 2010 and average annual growth of GDP is to be 6% [2].

Energy, and more explicitly electricity, is a pre-requisite for the technological development, higher economic growth and poverty reduction of a nation. The future economic development of Bangladesh is likely to result in a rapid growth in the demand for energy with accompanying shortages and problems. The country has been facing a severe power crisis for about a decade [3]. Known reserves (e.g., natural gas and coal) of commercial primary energy sources in Bangladesh are limited in comparison to the development requirements of the nation.

By acknowledging the potential of renewable energy resources, Bangladesh could possibly meet its unprecedented energy demand, thus enhancing electricity accessibility to all and increasing energy security through their progression. The country has modest hydrocarbon resources and rich renewable energy sources particularly in the form of traditional energy resources [1]. Appropriate integration of renewable energy technologies (RETs) in the power sector through national energy planning would be, therefore, the right direction, not only for sustainable development of the country but also as the responsibility of Bangladesh toward the global common task of environmental protection from pollution [3]. RETs have become multi-billion dollar industry from the realm of laboratories in recent years. At present, most of the large international oil companies have started serious business with renewable energies [4].

Renewable energy technologies (RETs) offer developing countries like Bangladesh some prospect of self-reliant energy supplies at national and domestic levels, with potential economic, social, ecological, and security benefits. Some RET models have already been implemented in rural areas in Bangladesh. However, these models do not specifically allow the poorest peasant control over RETs and the income generated by them. The major sources of renewable energy in Bangladesh include solar, wind energy, biomass and biogas, and hydro [5]. Other minor renewable energy sources are bio-fuels, gasohol, geothermal, river current, wave and tidal energy. Potentialities of these minor sources are yet to be explored.

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The existing circumstances in the electricity market in Bangladesh may offer unique opportunities for energy storage technologies, predominantly in combination with renewable energy generation, in which a few seconds to a few hours of electricity can be stored for use at a later time [6]. These systems can be positioned near the generator, transmission line, distribution substation, or the consumer's premise, depending on the application they are addressing. Storage can play a flexible, multi-function role in the electricity supply system to manage resources efficiently. Electric energy storage promises other benefits unrelated to renewable energy, such as superior grid reliability and stability, deferral of new generation and transmission investments, and other grid benefits [7]. In combination with renewable energy resources, energy storage systems (ESS) can increase the value of photovoltaic (PV) and wind generated electricity, by making supply coincident with periods of peak consumer demand [8].

This paper is organized as follows: First, a brief overview of current power situation in Bangladesh is presented in Section II to initiate the required impression throughout this paper. This is followed by a review of leading renewable energy resources available in Bangladesh in Section III, which have already found potential applications in different sectors. Section IV covers a brief surveillance on upcoming renewable energy based power generation projects. Energy storage system contributing renewable energy sectors such as battery is reviewed in Section V. Finally, in Section VI, possible economic developments using the RETs for rural people are discussed elaborately, which is followed by concluding remarks in Section VII.

II. Present Power Scenario in Bangladesh

Bangladesh is experiencing intimidating energy challenges: Security concerns over growing fuel imports, limited domestic energy resources for power generation. At present the power demand in Bangladesh is about 6000MW, whereas the generation ranges only 4000-4600 MW. The generation capacity is 5936MW [9]. As a result of power shortage causes excessive load shading throughout the whole year. Bangladesh relies greatly on fossil fuels for its energy, but the present reserve would be depleted by the year of 2015 [10]. Here, coal is still the major fuel for power generation. Bangladesh has adequate high quality coal resources. But the coal mining has not been started effectively. Exploration and development of natural gas resource has almost reduced to zero. Also the exploration of coal continues to remain uncertain. Consequently, the shortage of power can be met by renewable energy resources which are abundant in nature.

Table I : Present Power Scenario in Bangladesh

Sl. No.	Items	Status (2011) [9]
1	Electricity Growth	10 % in FY-2010 (Av. 7 % since 1990)
2	Total Consumer	12 Million
3	Transmission Line	8,500 km
4	Distribution Line	2,70,000
5	Distribution Loss	13.1%
6	Per Capita Generation	236 kWh (incl. Captive)
7	Access to Electricity	48.5 %
8	Present Generation Capacity	5936MW
9	Present Demand	6000MW
10	Present Available Generation	4000 – 4600 MW
11	Recent Maximum Generation s	4699 MW (20 August 2010)
12	Maximum Load Shedding in FY-10	1500 MW (during hot summer days)

III. Leading Renewable Energy Resources in Bangladesh

Renewables are an almost unlimited source of energy if one considers the energy necessary by mankind, compared with the huge amount of energy we receive from the sun. Gradually renewable energy and its different energy conversion technologies have become economically viable, capable of competing with fossil-fuelled technologies in the energy market. The size and economic potential of the renewable energy resources (e.g., solar energy, wind power, biomass and biogas etc.) in Bangladesh are yet to be determined and the capacity of renewable energy development is presently low. Although investment costs of renewables are generally higher compared to fossil fuel alternatives, this option becomes economically viable when all externalities (e.g. environmental cost, health hazards etc.) and lower operating cost are taken into consideration [11].

a) Solar Energy

The energy from sunlight reaching the earth is a huge potential that can be exploited and used for generating electricity. Among a number of available technologies, solar photovoltaic (PV) is the most promising. PV technology converts sunlight into direct current (DC) electricity. When light falls on the active surface of the solar cell, electrons become energized and a potential difference is established, which drives a current through an external load. The central issue for the PV technology is cost. The unit cost of PV has sunk in several orders of magnitude while the efficiency is continuously being improved. Solar PV is becoming more and more popular due to high modularity, no

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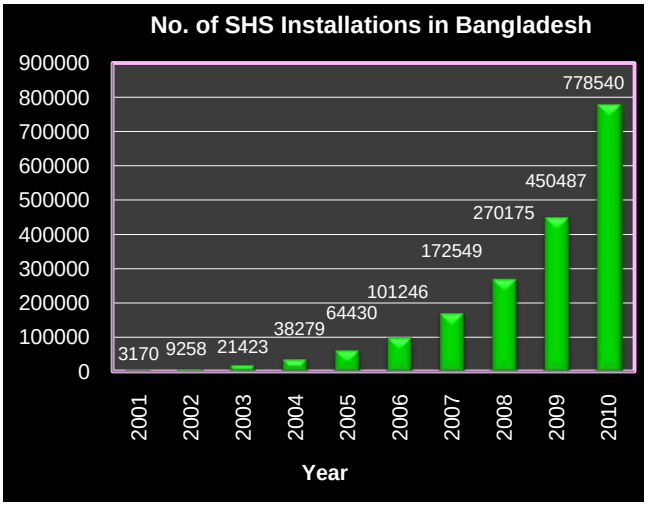
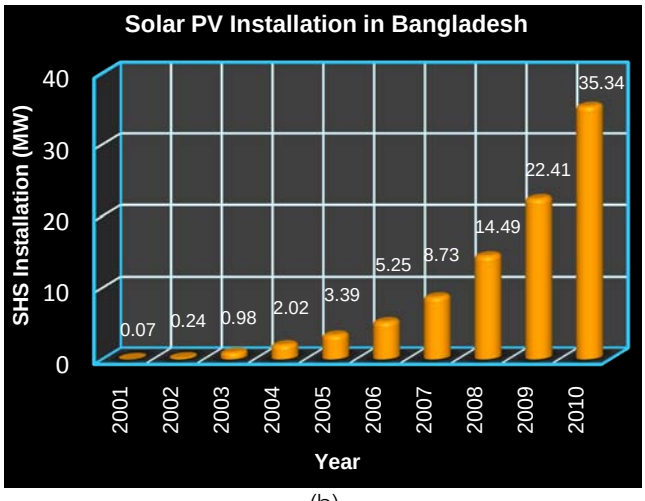
requirement for additional resource (e.g., water and fuel), no moving parts, and low maintenance needed. Over the last two decades, the cost of manufacturing and installing solar PV system has decreased by about 20 % for every doubling of installed capacity [12]. In the whole world solar power generating capacity grew by 70 % in 2008 and 47% in 2009, but still fast enough to leave global solar capacity at the end of 2009 more than twice as high as it was at the end of 2007. The solar industry has grown at a rate of 35 % per year over the last ten years [13].

Fig. 1: Installing a solar PV system in a rural area.



(a)



(b)

Fig. 2 : SHS Installation in Bangladesh [16]: (a) number and (b) equivalent power.

Bangladesh is located between 20.30 - 26.38 degrees north latitude and 88.04 - 92.44 degrees east which is an ideal location for solar energy utilization. Here, the daily average solar radiation varies between 4 to 6.5 kWh per square meter [4]. Maximum amount of radiation is available on the month of March-April and minimum on December-January.

Infrastructure development company limited (IDCOL) has supported NGOs in installation of solar home systems (SHSs) and a total of 801,358 SHSs having capacity of about 36.5 MW have been installed upto January 2011 [14]. Fig. 1 shows the installation of a solar PV system on the roof of a village house in Bangladesh. The number of SHS installed in Bangladesh is shown in Fig. 2 (a) and the equivalent power in Fig. 2 (b). It demonstrates that the rate of SHS installation is increasing significantly per year.

Bangladesh power development board (BPDB) has implemented an excellent Solar PV electrification project in the Chittagong hill tracts region. The Solar PV electrification has emerged as the most appropriate technological option for the electrification of these areas [15]. A 10 kW central AC solar PV system has been installed in one selected market in each of the three Rangamati district's sub-districts (Fig. 3). With these systems, the shops of that market have been electrified with normal AC electricity.

b) Wind Energy

The energy from continuously blowing wind can be captured using wind turbines that convert kinetic energy from wind into mechanical energy and then into electrical energy. Electricity generated by wind turbines can feed to the central grid or be locally consumed using small stand-alone wind turbines. Gradually

Fig. 3 : Solar Arrays of 10 kW centralized AC market electrification systems at Barkal, Rangamati.

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Fig. 4 : Wind turbines of 1000 kW capacity WBHPP at Kutubdia Island, Cox's Bazar district (Bay of Bengal).

Generation of electricity from wind energy becomes very much promising where speed and wind power density is sufficiently high [3]. Wind power generating capacity growth accelerated to 31% in 2009 through the whole world, with capacity increasing by a record 38 GW to reach 160 GW by the end of 2009. This was the sixth consecutive year of accelerating growth, a remarkable achievement in a year of global economic recession. Wind turbines for grid-connected systems are the most highly demanded on the market and the rate of capacity growth is 28% per year between 1999 and 2009 [17].

In Bangladesh, especially at coastal areas there are some islands and inlands where wind energy can play a very important role to progress the economy of the country. BPDB installed a 160 feet tower at the Muhuri Dam site in the Feni district in May 2003. Two high resolution anemometers were installed on this tower, one anemometer at 80 feet and the other at 160 feet height. One wind vane has been installed at 80 feet height. The average wind speed, till to date, at the Muhuri Dam areas is found to be as 6.50 m/s and the wind power density varies from 100 to 250 Watt/m^2 in the coastal regions of Bangladesh [18]. For the financial viability of the grid connected wind turbines, the required annual average wind speed is 6 m/s. So, the wind speeds are encouraging for the grid connected wind energy projects in the areas of the Muhuri Dam, Feni [19]. This site is large enough for the larger wind energy projects.

BPDB implemented a 1000 kW capacity wind battery hybrid power project (WBHPP) at the Kutubdia Island (Bay of Bengal) in the Cox's Bazar district (Fig. 4). Under this project, total 50 nos. of 20kW capacity stand alone type wind turbines are being installed. The total capacity of all the wind turbines is 1 MW. The wind turbines producing electricity is being stored in battery bank. WBHPP was officially started on March 30, 2008. In another project, BPDB has implemented a 0.90 MW capacity of the grid connected wind energy (GCWE) at the Muhuri Dam areas in the Feni district in 2004. The installation, commissioning and erection works of 4 units of the 225 kW GCWE turbines at this site had been completed in 2004. This is the first ever GCWE project in Bangladesh. Thus generating electricity from wind in the coastal areas can be transmitted to other regions of the country through the high voltage transmission lines [19]. Very little operation and maintenance will be required during the whole life time of wind turbines and no fuel will be required for generating electricity from wind.

c) Biomass and Biogas

Biomass is the fourth largest source of energy worldwide and provides basic energy requirements for cooking and heating of rural households in developing countries. Biomass covers all kinds of organic matter from fuel wood to marine vegetation. Energy generation using biomass offers a promising solution to environmental problems by reducing the emission of common greenhouse gases. There have several technologies for conversion of biomass into energy such as heat energy and electrical energy. Two widespread technologies are direct combustion and gasification. Direct combustion involves the oxidation of biomass with excess air, producing hot flue gases which in turn produce steam, which is used to generate electricity [20]. Gasification involves conversion of biomass to produce a medium or low calorific gas. The gained gas is then used as fuel in combined cycle power generation plants. Being produced in combined cycle power plants, electricity from this technology has higher efficiency and is more competitive than that from a steam turbine. Electrical conversion efficiencies up to 40% are possible on a scale of about 30 MW on the short term [21]. Anaerobic digestion of biomass has been demonstrated and applied commercially for a variety of feedstock, such as organic domestic waste, organic industrial waste, manure, sludge, etc.

Biogas is a mixture of CH_4 (40 – 70 %), CO_2 (30 – 60 %) and other gases (1 – 5 %) produced from animal dung, poultry droppings, and other biomass wastes in specialized bio-digesters. This gas is combustible and can be used to generate electricity [22]. Biogas can be applied for cooking and power generation. Biogas mainly from animal and municipal wastes may be one of the promising renewable energy resources of Bangladesh. It is a potential source to harness basic biogas technology for cooking and rural and peri-urban electrification to provide electricity during periods of power shortfalls.

Biomass is the most significant energy source in Bangladesh which accounts for 70% of the total final energy consumption [4]. This technology can be disseminated on a larger scale for electricity generation. IDCOL financed a 250 kW Biomass based power plant at Kapasia, Gazipur. The plant uses locally available agricultural residues i.e. rice husk as fuel for power generation. Being located in an unelectrified area, the plant is expected to supply environment friendly grid

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Fig. 5 : Construction of a biogas plant in a rural area of Bangladesh.

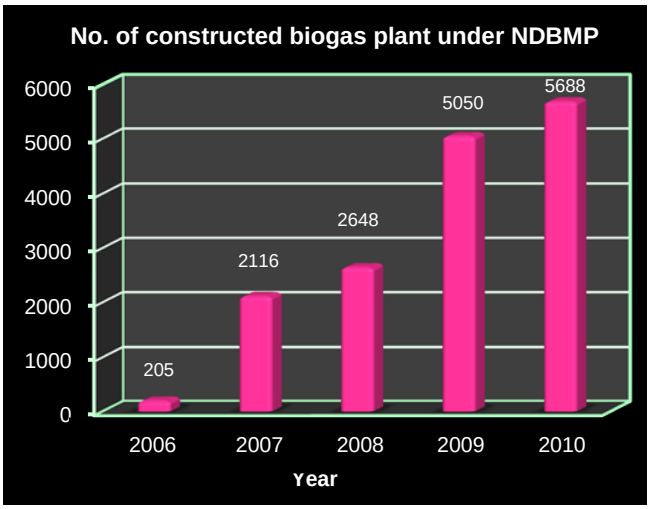

Fig. 6 : Biogas plants construction in Bangladesh under NDBMP [25]-[26].

quality power to 300 households and commercial entities of that area [23].

There are three million potential household with adequate cattle or poultry. In Bangladesh biogas is being used mainly for cooking purpose. From 1971 to October 2009 About 41000 biogas plants has been constructed by different NGOs, under national domestic biogas and manure programme (NDBMP) of IDCOL, sustainable energy for development (SED) program of German technical cooperation (GTZ), and other government organizations e.g. local government engineering department (LGED), Bangladesh council of scientific and industrial research (BCSIR) [24]. Under NDBMP of IDCOL, 5688 biogas plants have been constructed in Bangladesh in the year of 2010 (Fig. 6).

d) Hydro Energy

Kinetic energy from flowing or falling water is exploited in hydropower plants to generate electricity. Hydropower plants are classified into two categories: 1) Large hydropower plants (>10 MW), usually with reservoirs, that cannot only produce electrical energy Continuously, but also are able to adjust their output according to electricity demand and 2) small hydropower plants (<10 MW) that are less flexible with respect to load or demand fluctuation due to their dependence on the water resource [3]. Hydropower technologies are mature and widely available.

In Bangladesh about 1.4 trillion cubic meters (m^3) of water flows through the country in an average water year. Major rivers of the country have a high rate of water flow of about 5 to 6 months during monsoon season, which is substantially reduced in winter season. More than 90% of Bangladesh's rivers originate outside the country, due to which proper planning of water resource is difficult without neighboring countries cooperation. Downstream water sharing with India is a highly contentious issue for Bangladesh. The annual average rainfall is about 2,300 mm, which varies from 1,200 mm in the north-west to 5,800 mm in the north-east. Most of the rainfall (about 80%) occurs during the months of May/June to September/October [4]. At present only 230 MW of hydro power is utilized in Karnaphuli, Rangamati hydro station, which the only hydro-electric power plant operated by BPDB [27]. Microhydro and minihydro have limited potential in Bangladesh, with the exception of Chittagong and the Chittagong hill tracts. Hydropower assessments have identified some possible sites from 10 kW to 5 MW but no appreciable capacity has yet been installed [5].

IV. Renewable Energy Based Power Pants: Future Plan

Development of renewable energy in Bangladesh is insufficient. Besides the conventional energy, in order to promote the renewable energy the activities of sustainable energy development authority (SEDA) have been accelerated in Bangladesh. As per approved renewable energy policy 5% of the total generation (450 MW) would be added by 2015 and 10% of the total generation (1600 MW) would be added by 2020 from renewable sources [28].

With an average annual direct normal irradiance (DNI) of 2,000kWh/m^2, the area required to generate 100MW of electricity is about 2km^2. Bangladesh receives an average annual DNI of nearly 1,900kWh/m^2 which is adequate to operate a concentrating solar power (CSP) plant [29]. On March 14, 2011, Bangladesh has set a target to produce 500 MW of electricity installing solar home systems to reduce greenhouse emissions and ensure sustainable development in energy sector [30]. It also plans to install solar irrigation system to cut diesel cost.

BPDB established a wind resource assessment station (WRAS) at the Moghnama Ghat, Cox's Bazar. The installation, commissioning, erection, testing etc. works of this WRAS have been completed in December 2003. So far wind resource data of this site have been

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gathered and these data shows the clear viability of grid connected wind energy at this site [19]. Another WRAS installation at Kuakhata, Patuakhali is under process to measure the wind potential at that location.

In Bangladesh, about 8-9 million metric tons of rice husk is produced annually. So, theoretically there is a potentiality to generate 400 MW biomass gasification based electricity. Again, there are three millions of potential households with adequate cattle or poultry and it reveals the potentiality of 800MW biogas based electricity plant [24]. BPDB is considering extension of Karnaphuli hydro station to add an additional 100 MW electricity, which will be effective to operate it as a peaking power plant [4]. The additional energy will be generated during the rainy season when most of the year water is spilled.

V. Energy Storage in Renewable Energy Sectors

Energy storage improves the efficiency and reliability of the electric supply system by reducing the requirements for spinning reserves to meet peak power demands, making better use of efficient base load generation, and allowing greater use of intermittent renewable energy technologies. Energy storage can help to increase energy security, reduce the environmental impact of electricity generation, transmission and use, and broaden the diversification opportunities for utilities by adding more generation options to their portfolios [21]. Energy storage technologies include batteries, flywheels, ultracapacitors and superconducting magnetic energy storage (SMES) for short term storage and pumped hydropower, compressed air energy storage for long term storage [32].

Table II : Renewable Energy Projects [9], [23], [31]

Sl No.	Location of the Project	Capacity (MW)	Type of Project
1	Parki Beach, Chittagong	100-200	Wind Power
2	Moghnamogha, Cox's Bazar	10	Wind Power
3	Hatia, Sandwip, and Monpura Islands	4	Wind Power
4	Bazitpur, Kishoreganj	18	Grid Connected Solar PV
5	Kaptai, Rangamati	5	Grid Connected Solar PV
6	Sarishabari, Jamalpur	2-4	Grid Connected Solar PV
7	RTC, Rajshahi	1	Grid Connected Solar PV
8	Rajabarihat, Rajshahi	2-4	Grid Connected Solar PV
9	St. Martin Island	1.5	Wind and Solar Hybrid
10	Chilarong, Thakurgaon	0.4	Biomass

Lead-acid batteries are mainly used as energy storage systems in the renewable energy sectors in Bangladesh. Here, two types of industrial batteries are produced: tubular plate batteries, and flat type batteries. Because of the higher durability, consumption of tubular plate battery is higher than the flat type. Most of the tubular plate battery is now locally manufactured with a total capacity of 201,000 per year [16]. Major manufacturers include Rahimafrooz, Rimso, Hamko, Navana, Pannaand, and few others (Fig. 7). In terms of cost, 70% of the raw materials are imported and the major raw materials include lead, separators, casing etc.

Rahimafrooz batteries limited (RBL) is the largest lead-acid battery manufacturer in Bangladesh and offers an extensive range of automotive and specialised industrial battery. The company manufactures over 300 different types of automotive and industrial batteries. It has technical collaboration

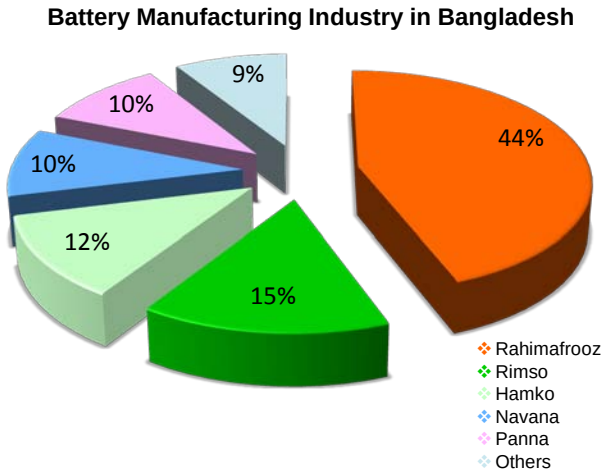

Fig. 7: Tubular battery manufacturers in Bangladesh[16].

Fig. 8: Battery bank of 1000 kW capacity WBHPP at Kutubdia Island, Cox's Bazar.

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Agreements with UK-based Lucas Battery Company, technical support group, Hawker batteries, Invensys and Hawker batteries, Eltek of Norway, and AEES of France, to ensure the quality of the battery [33].

The wind turbines using at Kutubdia Island, Cox's Bazar produce electricity and charges the batteries at battery banks as shown in Fig. 8, which consisting of 1000 numbers of 200AH with capacity of 12VDC [34]. The stored electrical power from the battery banks is converted to AC by using inverters and distributed to the consumers through overhead power cable.

VI. Economic Development Through Renewable Energy

Access to energy has become essential to the functioning of modern economics. To alleviate poverty in the face of resource limitations and high population density, Bangladesh requires an economic growth rate of more than 7%. In order to achieve this growth rate electricity growth need to be achieved by 10%. Commercial energy in Bangladesh is dominated by natural gas, particularly in power generation. This is supplemented by imported liquid fuel; indigenous coal is yet to make any significant impact in the energy scenario. While sustained energy supply is a prerequisite for economic development, current information indicates that the existing gas reserves will be able to meet the gas demand (at 7% per annum) up to 2016 though with the present production capacity it cannot meet the existing demand [28].

In Bangladesh the natural trend towards teledensity is growing. Moreover, the government is trying to implement a digital superhighway facility for the nation. Consequently, the need for communication equipment is of the first priority. It is therefore essential for the telecommunication operators to ensure a continuous power supply economically at the time of crisis. Solar energy can be the most suitable solution for alternate more reliable sources of energy. This will improve the the coastal region wind solar hybrid system Can ensure service of the telecom companies, and also allow them to cover off grid areas and thus contributing the rural inhabitants' financial development. Renewable energy technologies (RETs) could be selectively applied to various rural applications, potentially generating income, improving health and educational quality, and increasing labour productivity. However, such potential benefits arising from RETs may be realized only through a process that appropriately harnesses the social and financial context of village life. There are practical implementations of RETs in other rural situations that have succeeded in catalysing endogenous development, including job creation. Fig. 9 represents a model for addressing benefits of sustainable development of the rural poor using RETs.

VII. Conclusion

The summery demonstrates that there is considerable opportunity for Bangladesh to meet its future power demand and thus economic growing through renewable energy. Bangladesh already has experienced with sustainable energy projects and certain renewable energy project approaches. Though these initiatives are at initial stage of development and implementation, the potential of these initiatives is high. There are many possible ways in which these goals can be carried out in Bangladesh; through combinations of different renewables technologies, grid based generation and micro-renewables, and energy efficiency. In Bangladesh, diffusion of renewable energy technologies has gained momentum in recent years via evolution of relevant policies, institutional facilitation and learning-by-doing experience. Renewable energy policy has been adopted by the government of Bangladesh on December 18, 2008. Sustainable energy development agency (SEDA) will coordinate activities related to the development of renewable energy technologies and financing mechanisms in the country.

Bangladesh has got ample solar insolation throughout the country. Daily average solar radiation varies from 4 to 6.5 kWh/m^2. There is intense prospect of

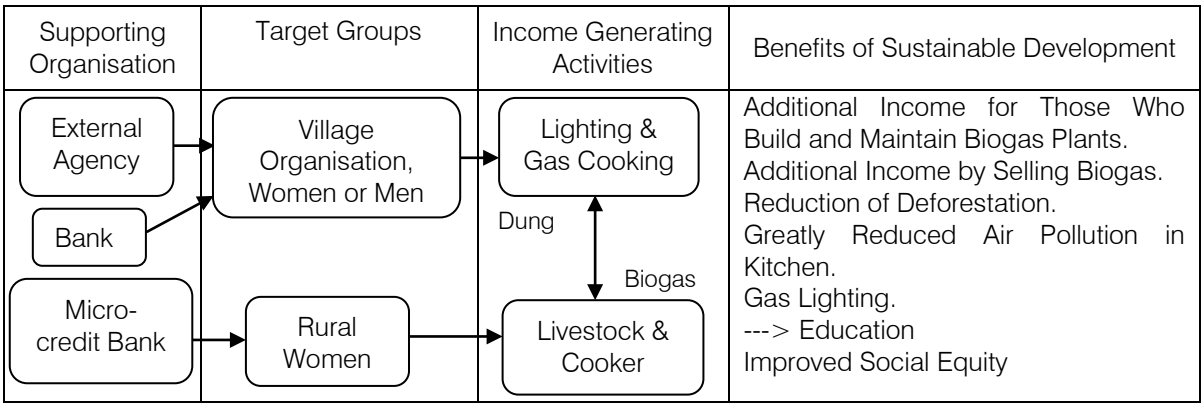

Fig. 9 : Simplified system using biogas.

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Solar photovoltaic and solar thermal systems in the rural as well as urban areas of the country. BPDB's established WRAS is expected to provide more valuable information regarding wind energy potential for larger projects in Bangladesh. Bangladesh consists of diverse potentials of biomass and biogas energy. Many waste-to-energy projects have proven budding applications of biomass and biogas which will not only provide electricity, but also reduce the unpleasant waste disposal problems of metropolitan cities of the country. There is limited potential of small hydro power plants in country. BPDB and Bangladesh water development board (BWDB) are presently working together to implement a pilot project at any of the prospective regulating structures of Tista Canal system.

Among the different energy storage technologies only batteries have found potential application in renewable energy sectors in Bangladesh and it shows a bright prospect in storage of electricity generated by renewables. This survey has been accomplished by the information available at the present time and more detailed statistics on energy use in Bangladesh. Finally a model has been developed in which it is shown that RETs, using appropriately, may improve the quality of life of rural people and provide income-generating opportunities with redressing social inequities and environmental impacts in Bangladesh.

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