Electric Energy Access in Bangladesh

Muhammad Taheruzzaman and Przemyslaw Janik*

Brandenburg Technical University-Cottbus, 03046 Cottbus, Germany

*Faculty of Electrical Engineering, Wroclaw University of Science and Technology, Wroclaw, Poland

***Abstract*— This paper represents the overall electrical energy profile and access in Bangladesh. In the recent past, Bangladesh has been experiencing the shortage of electricity, and about 42 % of the population no access to the electricity. The electricity consumption has rapidly increased over last decade. The demand and consumption will intensify in the remote future as overall development and future growth. To set "vision 2021" of Bangladesh; the government of Bangladesh has devoted to ensuring access to affordable and reliable electricity for all by 2021. In the modern time, energy is the vital ingredient for socio-economic growth in the developing country i.e., alleviating poverty. Along with electricity access in Bangladesh strived to become the middle-income country by 2021. Bangladesh has experienced that energy consumption inclines to increase rapidly when per capita income reaches between US$ 1,000 and US$ 10,000, and a country's growth momentum through reliable energy supply and consistent energy supply ensured by the sustainable energy. As increasing population in Bangladesh, the electric energy generation is an important dispute through the sustainable way.**

***Index Terms*— Energy Profile, Energy efficiency, Electric Power sector, Electricity reformation, Renewable energy access, Solar home system**

I. Introduction

According to report 2012, Bangladesh is the 134th ranked out of 144 countries on the quality of electricity supply, which suggests the most problematic obstacles to the further socioeconomic progress. The IEA estimates approximately 1.5 billion people have no access to electricity in 2008 [1], which estimates more than 20 % of total population. According to UNDP report more than 96.2 million of people which is more than half the total population in Bangladesh still remains without access to electricity city [2], furthermore, the irregular electric power supply causes load shedding. Electric energy access is the far-way dream for many families in the rural area in developing countries, about 80 % of the population are living in the rural and remote areas in Bangladesh where only 25 % of electricity available for people. Overcoming the curse of poverty, sustainable economic growth by access energy is an essential prerequisite and major criterion. Electricity access with a modern form of energy resources is promoting social and economic growth. It is also an indispensable contribution to achieving Millennium Development Goal (MDG) and vision 2021. In the modern era, there is no country attained sustained economic growth without improving access to clean and modern energy; the modern form of energy delineates with an integration of locally available renewable energy sources. Rural electrification ensuring with improved electricity is fundamental for socio-economic development. Electrical energy access influences to the life standards, which affecting agricultural productivity, education, health. The Government of Bangladesh has set a noble vision to access electricity for all inhabitants by 2021, to comply the vision integrating solar PV and biomass sources which are richly endowed in Bangladesh. In Bangladesh, it is common about 4 - 6 h of power outage per day in rural areas, but summer season the number of hours rises to 6 - 8 h, mostly during 18:00 - 22:00 h irregular power outage causes load shedding. The demand for electricity increases with increasing with Population but the generation of electricity is not increasing to meet the demand. At present, almost 52 % of total people in Bangladesh are connected to the grid [3], the power supply from the grid is inadequate to meet both peak and basic demand in Bangladesh. Almost 75 % of people in rural areas are not connected to the main grid, and only 15 - 20 % of electric demand comply by the BREB (Bangladesh rural electrification board) supplied electricity [4]. Due to life standards and social standards enhances, the consumption rate increased at 4.53 %, but the generation of electricity increased only at a rate of 5.37 % that increased

Muhammad Taheruzzaman (email: muhammad.taheruzzaman@tu-cottbus.de) Department of Energy Distribution and High Voltage, Brandenburg Technical University Cottbus, 03046 Cottbus, Germany

Przemyslaw (e-mail: janik@b-tu.de). Faculty of Electrical Engineering, Wroclaw University of Science and Technology, Wroclaw, Poland

© Muhammad Taheruzzaman & Przemyslaw Janik

the rate of 6.72 % load shedding per year [5], graphically present in figure 2-3. According to LEAP (long range energy alternative planning) project [6], rural households loads comprises with lighting, mobile charger, ceiling fan, TV, and refrigerators. In rural areas lighting are the main loads in the rural households. In 2010 rural households, consumes 300kWh per year for lighting solely satisfied by electricity supplies. The demand for lighting growing at constant 1.67 % per year to 350 kWh by 2020 [7]. A tropical country like Bangladesh, where summer seasons comprises almost 9 months requires cooling by the ceiling fan, consumes 250 kWh per year and assume the consumption rate increase up to 1.9 % to 345 kWh in 2030. Likewise, refrigeration consumption demand rate increase 0.93 %, the demand increases from 476 kWh to 565 kWh in 2030. The percentage of energy consumption has experienced promptly increasing about 2.69 % from 2012 to 2013, but still remains lowest per capita consumption. The studies of EIA, the consumption has increased dramatically over 52 % within the past decade [8]. If your paper is intended for a conference, please contact your conference editor concerning acceptable word processor formats for your particular conference.

II. General Country Profile

Bangladesh is moving towards achieving the tag of Developing country with an annual GDP almost 6 % over the last past decade [9]. Recently population thriving dramatically nearly 158 million and annual growth rate of 1.39 % over the past decade [10]. The majority of them are living in the rural areas, and only 32 % of households have access to electricity, but the availability of electricity about 22 % [11]. Bangladesh is one of the largest in population at 9th position in the world with 158 million people at the end of 2014, where total 52 % people have partially electricity access, while only 10-15 % of rural have the access to electricity demand mainly meets the light, ceiling fan, refrigeration, irrigation, productive uses loads. In Bangladesh, the electricity demand of all sectors including agriculture, commercial service, industry, and domestic services. The domestic households and industry sectors are consuming of electrical power about 43 % and 44 % respectively in total of about 87 % [12]. The GDP growth rates significantly depend on the production of a country, as Bangladesh is an agricultural and small size industrial production based country, and production always depends on electricity, the GDP growth and electricity generation growth present in figure 1. It is estimated that 1 % increase in per capita energy consumption causes an increase in per capita GDP by 0.23 %.

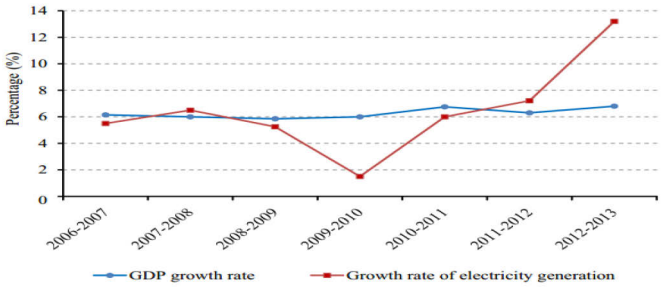


Figure 1: GDP Growth Rate with Electricity Access

A. *Demand of Electricity vs Climate of Bangladesh*

Bangladesh is located between 20° to 26° North and 88° to 92° east. It is bordered on the west, north and east by India, on the south-east by Myanmar, and on the south by the Bay of Bengal. The geographical location of Bangladesh offers higher solar irradiation [13]. Bangladesh enjoys generally a sub-tropical monsoon climate while there are six seasons in a year, with three being more prominent, namely winter, summer and monsoon season. Winter begins in November and ends in February. In winter, there is not much fluctuation in temperature, which ranges from minimum of 7° - 13 °C to a maximum of 24 °C – 31 °C. The maximum temperature recorded in the summer months is 37 °C although in some places this occasionally rises up to 41°C (105°F or more) [13]. As the temperature increases the demand for electricity has increased due to refrigeration, cooling, whereas the base load demand is higher than the electricity generation. Bangladesh has three main seasons: the monsoon or wet season from late May to early October; the cold season from mid-November to the end of January; and the hot season from March to mid-September [15]; the imbalance between demand and supply due to high electricity demand for ceiling fan, refrigeration during March to August in each year.

B. *Electric Energy Status and Demand Profile*

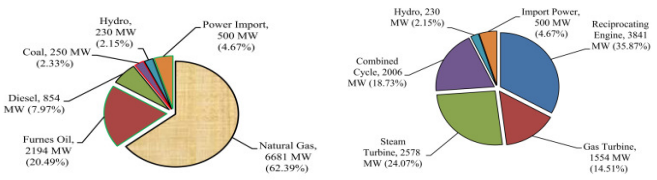
Electric energy is one of the affable terms of energy which is the fundamental contingent for socio-economic development, which alleviate poverty. But, Bangladesh has the major problem of the energy crisis that persisting poverty, conventional fossil fuel causes environmental degradation. Merely, 49 % of the population have the access electricity that met by 4500 MW while peak demand 6000 MW causes the power outage. Currently, 53 % electricity produced by public sectors and rest produced by several private sectors with various form of generation [16]. The existing available power generation 8,500 MW by October 2014 and vision set to 39,000 MW by 2030 [17]. The (table-1), represents power generation from different organization and Bangladesh Power Development Board (BPDB) transmits and distributes across the country. Natural gas and coal expected the main source of power generation in Bangladesh, GOB also attentive on liquid fuel

based power generation. The conventional fuel consumption to generate electrical power and traditional power plant influenced to increase CO_2 emission, power generation sector alone contributes 40 % CO_2 emission [18]. The primary energy considered to consumption estimated 62% of biomass, 25 % of natural gas, 12 % imported oil, and coal and hydropower contribute 1 %.

Table 1: Daily Power Generation

Company	Demand (MW)	Day peak (MW)	Evening peak (MW)
Power Development Board	4332.00	1767.00	2702.00
Electricity generation company Bangladesh Ltd	622.00	0.00	0.00
Ashuganj Power Station Co. Ltd	1617.00	723.00	896.00
Independent Power Producer (private)	325.00	248.00	283.00
Small size producers	1987.00	1269.00	1440.00
Rental Power Producers	825.00	1101.00	1189.00
Total generation	10390.0	5515.0	6987

In Bangladesh, power sectors that highly dependent on conventional fossil fuel including gas and coal. The total capacity of electricity generation about 8,709 MW, and 62.9 % of electricity generation by natural gas present in figure 2. Besides natural gas, 10 % high-speed diesel, 5 % of coal, and 3 % of heavy fuel oil used to produces electricity figure 2(a). Besides natural gas, 10 % high speed diesel, 5 % of coal, and 3 % of heavy fuel oil used to produces electricity [20], and only 3.3 % of electricity contributes by renewable sources [21].



(a) (b)

Figure 2: Installed electricity capacity (a) fuel type and (b) plant type [19]

According to (BPDB) report expresses, 55 % of people have access electricity, and per capita 321 kWh electricity generation [22], which comparatively lower than other developing countries. Access to power in Bangladesh is limited to about 45 % – 50 % of the population and those who have access faces severe power shortages. Load shedding in Dhaka in 2011 and during the summer of 2012 was about 5 hours per day. Power shortages have constrained the potential economic growth in Bangladesh and cost of which have been estimated to be about 0.5 % of GDP. According to "Vision 2021"; the government's vision for the power sector is to ensure universal access to grid electricity by the year 2020, with an interim target to reach an access level of 68 % by year the 2015. According to government estimates, about 20,000 megawatts (MW) of new generation capacity need to be added to the system by 2020, together with matching transmission and distribution improvements to reach the universal access [23].

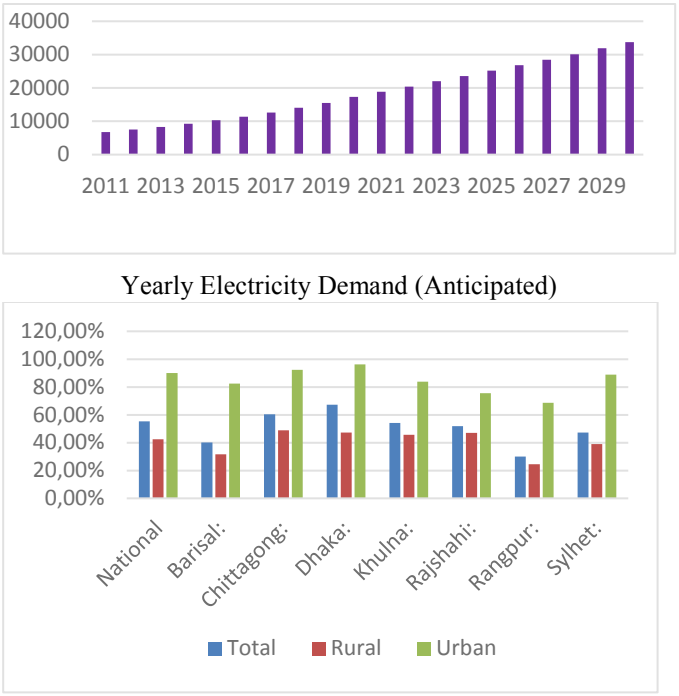


Figure 3: Electrification Rate in Different Regions

The total installed capacity was 5262 MW in FY 2007–08, which has increased to 8525 MW in FY 2012–13 with an annual increase of 10.34 %. However, the maximum generation was 4130 MW in FY 2007–08, which has increased to 6350 MW in FY 2012–13 with an annual increase of 8.96 %. The annual rise in maximum generation (8.96 %) is lower than that of the installed capacity (10.34 %) between the FY 2007–08 and 2012–13. This is mainly due to the less generation capacity of older power plants and shortage of gas supply.

Table 2: Different fuel Consumption

Gas	Diesel	Hydro	Coal	Furnace
4822 MW	186 MW	230 MW	250 MW	335 MW
82.81%	3.19%	3.95%	4.29%	5.75%

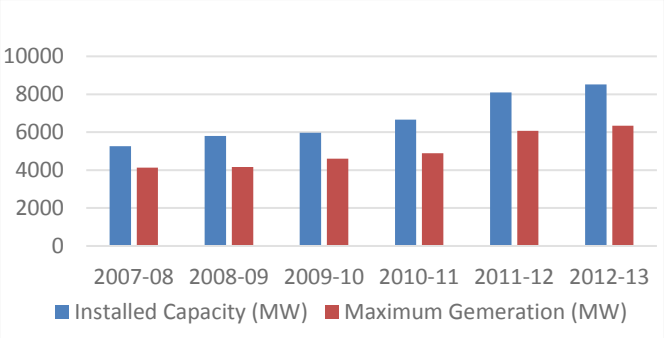


Figure 4: Installed Capacity and Generation 2007-2013

Though attribution is difficult, this technical assistance may have played a role in supporting a 'balanced development' of the power sector, which during the project period (2004-2013) saw an increase in electricity access from 35 percent to about 62 %; an increase in generation capacity from 3,622 MW in 2004 to 9,500 MW; a reduction of systems losses from about 20.0 percent to 1.3 percent; and a drop in accounts receivable from 6.45 months to 2.21 months. About 40 % of electricity generated by private enterprises by April, 2010 while the number has been increased to 44 % by April 2011. Currently, rental, quick rental and some others peaking plants were under taken on a first track based power generation to manage present power crisis. According to the Power System Master Plan (PSMP), the peak demand anticipated 10,283 MW in 2015, whereas total power generated about 12071 MW. The anticipated peak demand 25199 MW anticipated in 2020 and 33708 MW in 2030 show in figure 5.

C. Infrastructure of Bangladesh Power development

First Bangladesh Power Development Board (BPDB), is the sole authority to delivered electricity to the national grid through a common transmission line, to meet the national demand BPDB produces and purchases electricity from independent power producers (IPPs). The five authorities contributes together to produces electricity in Bangladesh:
(i) Bangladesh Power Development Board (BPDB)
(ii) Ashuganj Power Station Company Ltd. (APSCL)
(iii) Electricity Generation Company of Bangladesh (EGCB)
(iv) North West Power Generation Company
(v) Independent Power Producers (IPPs)

Table 3: Authorities of Power Generation and Capacities and Market Share

Name of Authorities	Capacity (MW)	Market Share (%)
Bangladesh Power Development Board (BPDB)	4442	42.75
Ashuganj Power Station Company Ltd (APSCL)	682	6.56
Electricity Generation Company of Bangladesh	622	5.98
North West Power Generation Company Ltd	375	3.06
Independent Power Producers (IPPs)	4269	41.08
Total	10390	100

Considering country size and population, Bangladesh electricity infrastructure are quite smaller than other countries which is insufficient and poorly managed by several authorities including BPDB, BPDC, DESCO and REB. Amongst all these authorities, REB is one of the most success government company since 1977 in Bangladesh, 40.10 % electricity purchased to electrifying rural areas.

Table 4: Share of electricity distribution by Authorities

Authority	BPDB	DPDC	DESCO	WZPDC	REB
Share (%)	24.64	18.59	10.51	6.17	40.10

Bangladesh power system including transmission system comprises along with 16 substations capacity of 230/132 kV besides that 103 substations dimensions of 132/33 kV substations, which total capacity of power contains 7525 MVA and 11892 MVA respectively. The distribution network comprises 33 kV, 11 kV, and 400 V [27].

III. Rural Electrification

South Asia accounts for 37 % of the world's population without access to electricity [28]. Such a situation continues to exist despite several initiatives and policies to support rural electrification efforts by the respective country governments including the use of renewable energy technologies including PV, wind, and biomass. The pace of rural electrification over much of the developing world is excruciatingly slow. In many countries in South Asian and Sub-Saharan African, it is even lower than rural electrification growth in Bangladesh. Bringing the socio-economic development into the development countries like Bangladesh, the essential elements considers rural electrification [29], development of underprivileged rural people [30] [31]. Demand for electricity with an improvement of living standard, agricultural production, community development in Bangladesh. Energy access through rural electrification level still not sufficient enough, but the impressive SHS growth and off-grid PV system in

Bangladesh. Development and implemented by IDCOL (Infrastructure Development Company Limited).

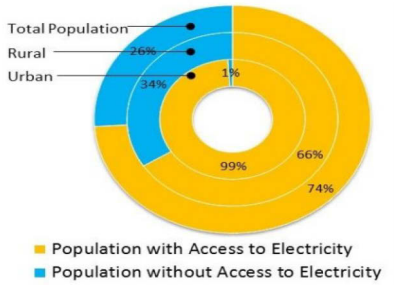


Figure 3: Electric Energy Access

Electrification rate in rural areas still poor as only 38 % of households is electrified [11], IDCOL (Bangladesh Government owned agency) with other 30 partners Organization (POs) working together for improving the access of electricity around rural areas. Despite of continuous efforts from the international community and governments, the pace of rural electrification still very slow [34]. The Bangladesh Rural Electrification Program (BREP) clearly expresses which benefit greatly from the involvement of local communities improve electricity access in rural areas. According to the vision 2021; GOB aims at 100 % access to electricity to entire rural areas by 2020, Connecting over 0.7 million consumers and only 3 % of electricity supplied by the REB, the dedicated government organization, rest of can be supplied by the including private company and partner organization (POs). The process of rural electrification in developing countries, which depends on various factors;

(1) The result of pre-phase economic and social impact
(2) Development of PBS (local partner)
(3) Technically and financially power system
(4)Available funding from international; community

There is the main process of electrical access in rural areas centralized approach and decentralized approach; centralized approached constituted by government and partner stakeholders. In Bangladesh REB and BPS are the main organization for rural electrification. The decentralized approach formulated by both top-down and bottom-up concept, standalone PV system, SHS, and renewable integrated hybrid mini-grid the best example in Bangladesh. The approach follows up and development of rural electrification in Bangladesh considered;
(1) Extending and intensifying the central grid
(2) Deploying off-grid technologies (off grid mini-grid, standalone MG, bottom up swarm electrification)

To implement the rural electric cooperative concept in Bangladesh, a central statutory agency called the Rural Electrification Board (REB) was formed by the government. The REB was given the responsibility of organizing the rural electric cooperatives (Palli Bidyut Samity, PBS); it employed managers to oversee the financial and administrative activities of the cooperatives. According to the World Bank manifesto, to bring most of the people electrifying under project "Rural Electrification and Renewable Energy Development" which mainly deployed by PV system [43].

A. Features of Rural Electrification

Before 1977, the government-owned Power Development Board (PDB) was the sole organization providing electricity throughout the country, without there being any special emphasis on rural areas. This actually left rural areas a very little chance to get access to electricity, and so, given this situation, the country launched the Rural Electrification Program (REP), which exclusively targets rural areas. The features of rural electricity in Bangladesh characterized by low voltage loads and distributed medium voltage lines. The power supply is unreliable and about 6 to 8 hours per day and phase imbalance. Average rural electric loads from 5 kW to 20 kW per village, and load factor around 0.2 to 0.3 (average demand/maximum demand). The load consumption in the households in rural areas are predominantly lighting, agricultural pumping, and mobile charge. The grids in a rural region often weak and high peak demand during evening lighting and summer agricultural pump. To implement the rural electric cooperative concept in Bangladesh, a central statutory agency called the Rural Electrification Board (REB) was formed by the government. The REB was given the responsibility of organizing the rural electric cooperatives PBS (Palli Bidyut Samity); it employed managers to oversee the financial and administrative activities of the cooperatives.

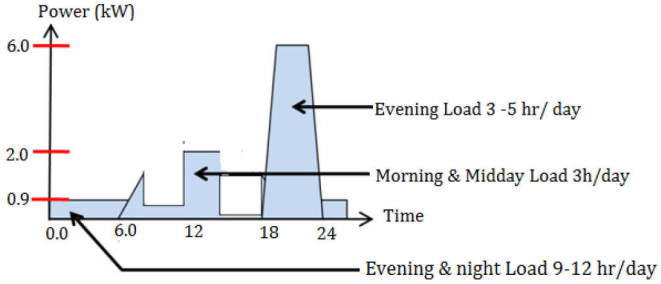


Figure 4: Typical Household Load Profile

B. Electric Energy Consumption Profile

In the modern epoch, electricity is the fundamental infrastructural input for economic development. Electricity is the flexible form of energy that drives development factors including industrialization, extensive urbanization, and intensification of living standards and modernization of agricultural sector. In Bangladesh Electricity is a major source of energy to meet the industrial and agricultural sector, both of these sectors contribute to 50.3 % of country's GDP [35]. Historically, Bangladesh is standing at overwhelmingly electricity generation by natural gas-based. According to the estimation of IEA, 1,400 MW electricity generation from 400 million cubic feet of natural in each day (IEA, 2014). In Bangladesh, natural gas supplied for consumption from two sources; state owned Petro-

Bangla, which contribute 99.4 % and international oil companies (IOCs) which account for 0.5 % of total supply.

Customer Category	Unit Price (tk/kWh)*
Category A: residential	
Life Line: from 1 to 50 unit	3.33
First Step : From 1 to 75 unit	3.80
Second Step : From 76 to 200 unit	5.14
Third Step : From 201 to 300 unit	5.36
Fifth Step: From 401 to 600 units	8.70
Sixth Step: Above 600 units	9.98
Category B: Agricultural pumping	3.82
Category-C : Small Industries	
Flat Rate	7.66
Off-Peak Time	6.90
Peak time	9.24
Category D: Non-Residential	5.22
Category E: Commercial and Office	
Flat Rate	9.80
Off-Peak Time	8.45
Peak Time	11.98

80 tk= 1 US $

IV. Renewable Energy penetration in Bangladesh

According to IEA Energy Access to comply the rural electrification, household having reliable and affordable electricity to clean cooking facilities, first electricity connection, and increasing level of electricity consumption over time as regional average. Bangladesh is the most potential country for renewable energy, significantly increases the number projects to meet the electrical energy throughout the country. The most existing form of renewable energy experienced in Bangladesh considering PV based off grid system including SHS, nano-grid, and mini-grid, where biomass also have high portentous to integrated significantly. With increasing both life and social standards urbanization is rapidly growing in developing countries, as comply urbanization growth electricity demand also increases promptly in Bangladesh. GOB has set target about 90 % electricity access across the country by 2018 [36] , to meet this vision innovative rural electrification integrated renewable energy is the best solution followed by the recent experiences, and achieving the target 2018 by connecting 450,000 households per months by 66 % SHS, and hybrid power system with renewable sources.

Although Bangladesh is the seven largest natural gas producer country among Asia, about 56% of gas consumption as the primary source of energy. As high dependency on natural gas, and experiences shortage of gas supply. The regular peak demands 5500 MW, but only 4000 MW of electricity produced by the conventional power generation system in 2007 that causes rolling electricity blackout. Remote areas and rural villages are the major mechanisms of holistic society; the development of socio-economy and environmental prominence in Bangladesh depends on productivity, and the productivity depends on access to energy. But the true reality is the government of Bangladesh not frequently involves for rural development including rural electrification due to some geographical constraints. In figure 7 represents, the electricity access increasing rapidly from 2000 to 2015.

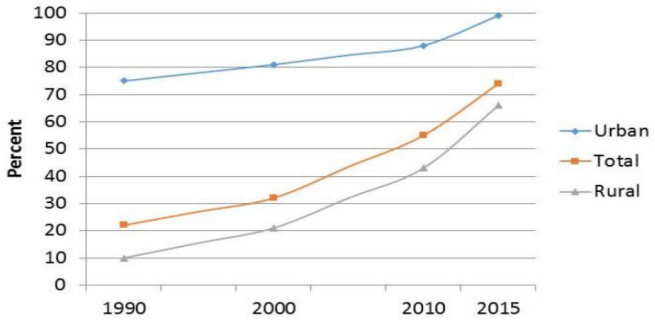


Figure 5: Change in Access to Electricity, 1990-2015

Electrifying in rural areas by conventional electrification system is expensive due to households are situated scattered and remote, and consumption rate low compare to urban electrification. Hence, no-electrified remote areas and poor villages electrifying by the conventional basis not promoted and focused. Consequently, it is urgent for the development of social life in Bangladesh by the availability of a reliable, adequate, and reasonably priced source of energy that uninterrupted balance of electricity supply.

Many countries and cities have already moved towards low carbon and clean energy transformations. Such as in Germany, for instance, is undertaking the 'Energiewende', an economic watershed that aims to produce 80 % of its electricity from renewable by 2050 [37]. Harnessing clean, renewable, and more efficient energy solutions will contribute not only to tackling a country's or community's energy challenges but also to the target of limiting global temperature rise to two degrees Celsius. As it is, a significant amount of GHG emissions are generated from energy production, thus tying sustainable energy directly to the climate change negotiations. Bangladesh today faces a different future than it did decades ago when abundant natural gas seemed to be the key to prosperity. At the same time as the centralized grid-based electrification has been the most common approach, decentralized renewable energy options especially, PV(photovoltaic) systems has also been adopted, especially for areas where it is techno-economically not feasible to extend the electricity grid.

These off-grid communities are generally small, consisting of low-income households with characteristics that may have been economically unattractive to electricity distribution companies to extend the grid. Small-scale renewable energy options, such as a solar home system (SHS) and biogas plants, have evolved as promising alternative for providing electricity to these disperse areas [38]. Other renewable energy options, such as wind energy and hydropower, have little potential to contribute to rural electrification in Bangladesh. Among the renewable technologies, the SHS option has accounted for the major share (80 %) of off-grid technologies in Bangladesh [39] [40] [41]. Bangladesh started its intensive rural electrification program in 1977 when only 10 % of its total population was connected to a grid. The country adopted a rural electric cooperative (REC) concept from the National Rural Electric Cooperative Association (NRECA), which had successfully electrified rural America in the 1930s [42]. According to the World Bank manifesto, to bring most of people electrifying under project "Rural Electrification and Renewable Energy Development" which mainly deployed by PV system [43].

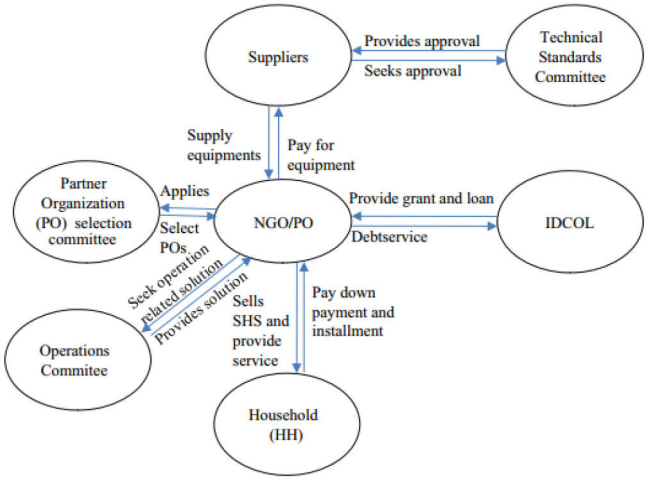


Figure 6: Institutional development for off-grid program

Amongst 49 partners' organization, IDCOL has developed a competitive market for Solar PV system without any geographic constraints by offering solar incentives; SHS installation, PV system with battery and charge controller supplies across the country [44]. Achieving quality and reliability of electricity supply is an important factor for each region, enhancement of reliability factor in integrating intermittent renewable energy like solar and the wind no choice except diesel generators, issues highlighted by (Foster and Steinbuks, 2009), estimates power system that generators owned compensated by 6 % of total capacity in Sub-Saharan Africa and other low-income countries up to 20 % [45]. Renewable electrification inspiring by the institutional framework in Bangladesh present in figure 8. Since renewable energy emerging in the power system of Bangladesh, the capacity gained 78 MW until 2012 which about 95 % of solar energy [46]. To comply the master plan, targeting 30 million of population electrified by off-grid system by 2016 which is about 18 % of the total rural population, whereas the number was about 15 million in 2013.

A. Biomass Potential

It is proved that Bangladesh has significant potential in biomass and biogas. Bangladesh is a tropical monsoon region, and agricultural is the main income for people who are living in the rural areas. Agricultural waste provides an enormous amount of biomass resources' assimilate with animal waste, household waste, and MSW which utilized to produce a large scale of electricity. Biomass generation system offers a number of advantages, mainly sources in low cost but high in energy efficiency compare to other fossil fuel, which reduces fuel costs. Besides electricity generation, biomass waste also affords fertilizer simultaneously. In Bangladesh gas is the main source of electricity production, according [47] about 88.8 % electricity generated by domestic gas, and a big part of electricity generation from imported furnace oil. In Bangladesh, from agriculture produces rice, wheat, maize, coconut, vegetables, jute, sugarcane, etc. About 46 % biomass energy sources from rice, straw, rice, husk, jute stick, sugarcane [48]. Most of the households in Bangladesh produces their vegetables and summer and winter accounted 48.16 % and 51.84 % respectively in the year 2011 [49].

Power generation from biomass gasification is reasonably novel in Bangladesh and favorable technology. Electricity generation by biomass gasification can be solved our day to day problem at an immense scope. Eventually, the purpose of rural electrification which is the expression of grief need of Bangladesh. In addition to producing electricity, it is advantageous to the agricultural and industrial expansion and production. It is almost impossible without rural electrification to meet the Bangladesh Government vision of ensuring access to reliable and affordable electricity for energy security-2020. Biomass and natural gas are the major sources of energy in Bangladesh, whereas 70 % biomass energy consumption of total energy consumption [39]. Biomass encompasses of agricultural residues in Bangladesh mainly rice, maize, wheat, coconut, groundnut, bean, vegetables, jute, and sugarcane etc. About 46 % of total Biomass energy has produced from agricultural crop residues. Rice is the main agricultural crop, and 70 % of rice husk energy is consumed. At present, NGOs are promoting small scale biomass system for clean cooking and electricity generation. There are two minor projects which supported by IDCOL those generating 200-300 kW by using poultry litter, moreover, the studies also suggested that up to 800 MW electricity by poultry waste litter. At present 15.00 tons of poultry litter produced each day, and a small fraction being used recycle. About 47 tons of waste expected, will be produced in 2025. In Bangladesh another available but significant raw material for biomass production rice husk, several search has shown that up to 400 MW of electricity can be generated single-handedly by rice husk.

B. *Photovoltaic Potential*

Bangladesh is blessed with enormous solar potential, as solar insolation. The average solar energy incident from 4 kWh/m²/day to 6.5 kWh/m²/day, with average 10.5 solar hours and about 300 clear sunny days. By the combination of a solar cell in PV module, under standard test condition (STC) module produces DC electricity at range 100 W to 400 W. In (figure 9) shown, clear bright sunlight, except June and July, average 7 to 9 h operates rest 10 months to produces solar energy. In figure 2-10, represents monthly average solar irradiation in different regions in Bangladesh.

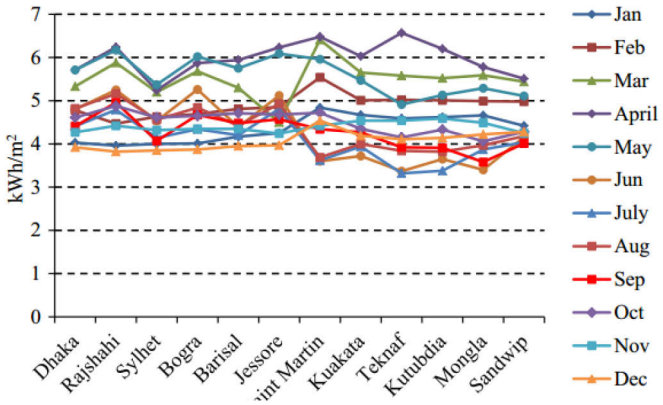


Figure 7: Solar Irradiation of different areas in Bangladesh

C. *Solar Home System in Bangladesh*

Solar sources and SHS has experienced a great success in Bangladesh, particularly the improvement of rural electrification. Currently, about 42 % of people have access electricity and per capita consumption of electricity is about 133 kWh in 2005 [52], which is the lower comparatively other developing countries. Nevertheless, the imbalance power supply makes a big difference between demand and supply, which makes load shedding. Started early 1980, PV flourished across the country and the success factors focus on; (i) Rural Areas electrified which are not yet accessible into the main utility grid. (ii) Remote areas where electricity access is almost impossible. (iii) Insufficient power supply.

.

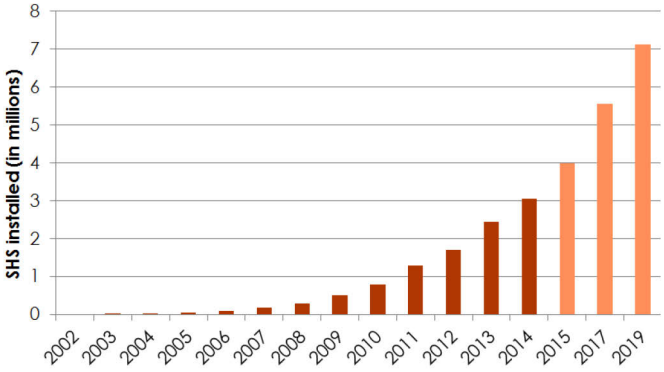


Figure 8: IDCOL SHS Program and Growth rate [56]

SHS generated electricity mainly used in rural households' loads including low power devices, CFL or LED lights, TV, mobile charger [53]. Bangladesh annual variation of inclination of the sun, measured from the vertical varies from 0 to 46 degrees between the summer and the winter. Summer days are longer, around 14 hours, with average sunshine more than 6kW-hr/day on clear sunny day. Although winter days are shorter around 10 h, still there is more than 4.5kW-hr/day of insolation on a clear sunny day. Solar Home System (SHS) are stand-alone photovoltaic systems that offer a cost effective mode of supplying power for lighting and appliances to remote off-grid households. In remote areas, which are not connected to the grid; SHS can be used to meet remote household's energy demand. In Bangladesh, SHS usually at a rate of 12 V DC and provide power for low power DC appliances including lights, TV, mobile charger, for about four to five hours. In developing countries like Bangladesh, where the national grid extension is not economically and technically feasible, an array of PV cells is used to build SHS. The main components of SHS include a solar panel, battery and a charge controller which can be operated with minimum training [54]. Over the past decade, since the Bangladesh government launched a rural electrification program supported by World Bank and other international aid bodies, the number of off-grid installations in the country has rocketed. In 2002, installations rates stood at 7000; today the figure has exploded to nearly 2 million and continues to count, with average installation rate now topping 80,000 per month [55].

IDCOL with other partner organization financed by World Bank 3357609 SHSs established until October 2014, and the numbers increase intensely present in (figure 2-11). The capacity achieved by SHS about 150 MW in the year 2013-2014, and growth rate increases about 185 %from the previous year. In 2015 the growth rate increases to 300 % and capacity raised 234 MW electricity generation potential from SHSs [57]. Generally distance between SHS about 2 to 2.5 meter, where most of the system capacity configured with 60 WP. As shown in (figure 2-11), SHS program promoted to increases more than 3.7 million by May 2015 [56], about 98 % of SHS installed through IDCOL [58], and additional 70,000 SHS being installed every month, and targeting more than 6 million more SHS by 2016 [59].

V. Innovation Approach for Rural Electrification

To achieved the Millennium Development Goals (MDG), electrification across nationwide is one of the main topology widely believed contribution, renewable sources deploy to sustainable development which leads to improvement of environment and fosters of socio-economic life. In the modern time, only 11 % of people have the access electricity in the Sub-Saharan countries [60], whereas in Bangladesh about 40 % of households have the access electricity [61] and the improvement rate of electricity

through SHS system and bottom-up swarm electrification successfully experienced in Bangladesh past decades. The households and communities are far away from the main grid and grid extension are not always cost effective due to infrastructure and insufficient power supply.

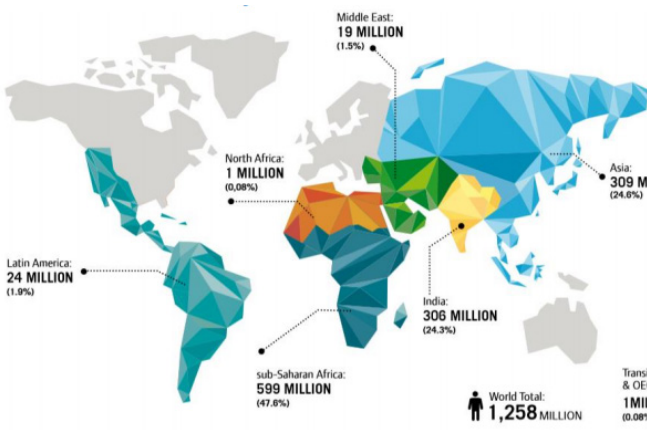


Figure 11: Word wide electricity access through Rural Electrification [62]

According to the authors' of [63] suggested, DC microgrid configured by several distributed generation such as SHS and from a local grid that might connect to the main grid. A mini-grid can be configured by local distributed generation system and the distributed generation sources' considering along with renewable resources such as PV, biomass, wind. According to swarm electrification concept, neighboring households are assimilating in an intelligent network where scheme allows sharing their information about supply, demand, and battery status within. To achieve this network by sharing electricity among participants within the scheme, consequently swarm network have the ability to integrate with legacy based where participants have the ability to produce electricity and consumption simultaneously, in order to propagate without or with limited number single centralized unit which has the ability to function independently may be called nano-grid. It is obverses that a sunny day an SHS in Bangladesh does not utilized their own capacity respect to their lords connected within the system, and 30% surplus electricity available for others [64]. Tier based Swarm concept explain in figure-13 and figure-14, tier-1 represents an SHS configuration and the loads consumption, self-generated electricity from PV panel. Tier -2 and tier -3 countenance SHS and BHS connected and formed a DC cluster, and tier -4 cluster grid also allow to connect to the grid to sellback surplus electricity. The major strategies for rural electrification to access electricity for all, some studies expressed only about 30 % of rural areas electrified by the centralized grid, whereas 70 % people can be electrified by the small scale nano-grid or microgrid [65].

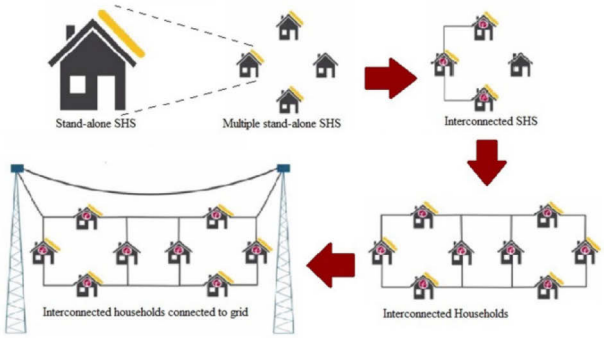


Figure 2: Swarm Electrification concept and stepwise approaches [66]

VI. Reforms and Policies Towards Renewable Energy

Declining the fossil fuel along with natural gas, the electricity production reduces whereas demand increases day by day. GOB has restricted and privatized the electricity generation sector by national Energy policy (NEP) in 1996. The major target of the policy to increase the power generation to meet the desires present and future demand which adopted by following policies:

I. Harnessing solar potential, and dissemination of RET in both urban and rural areas
II. Enable and encourage facilitate public and private sector investment towards RE projects
III. Development of sustainable energy system to substitute non-renewable sources
IV. Facilitating renewable energy at every level of energy including households to commercial and industrial

The national Energy Plan (NEP) envisions 5 % pf total renewable generation from renewable sources, and by 2020 achieved by 10 % energy from renewable.
Bangladesh Power Development Board (BPDB) imposed the bulk tariff for electricity consumption for distribution companies including Dhaka Electric Supply Company (DESCO), Dhaka Electric supply Authority (DESA), West Zone Power Distribution Company (WZPDC), Dhaka Power Distribution Company (DPDC), and Rural Electrification (REB). The distribution companies are working in the urban areas and REB with 77 rural electric cooperatives Palli Bidyut Samity (PBS) working for electrification in villages and remote areas.

VII. Conclusion

It is clear that most of the countries including low-income and developing countries GDP affected by the level of energy consumption, and per capita 0.23 % GDP increases by consuming 1 % of per capita energy consumption. The

growth rate of electricity has increased by 5.5 % in the fiscal year 2006-2007, which rapidly increased to about 13.2 % in the fiscal year 2012-2013. Likewise, the GDP of Bangladesh has increased at the rate of 6.8 % in the fiscal year 2012-2013 from 2006-2007 observed at rate 6.15 %. Bangladesh is the fast growing developing country, socio-economic, industrialization, other development booming while demanding of electricity increases day by day. Currently, power sector of Bangladesh produces 7,445 MW by 2012, and 8002 MW by 2016 along with different government entities and non-government company working together to meet the electricity demand. Almost 72.42 % of total electricity generated from natural gas in the fiscal year 2013-2014, and on the other side, the renewable penetration only about 2.5 % which is the insignificant comparison to global power generation.

In the present time Bangladesh is one of the market leader of SHS, and standalone PV system. In Bangladesh average 4 to 6.5 kWh/m^2 solar irradiation, and Maximum amount of solar radiation is available almost each month except December-January, however, 300 high sunny days suggested solar generated system like standalone PV system, and SHS. IDCOL and other 47 partner organizations (POs), NGO working together to installing 3 million SHS by 2013 and targeting almost 7 million by mid of 2018.

The conventional power system is expensive to configure and present demand is lagging behind from the continuous power supply to electrification, especially for electrifying rural and remote areas. Notwithstanding, the conventional trends to generates electrical power from the top-down grid, and author convinced to follow up the concept of bottom-up swarm electrification would be the best solution for electrifying rural areas in developing countries. A robust grid can be formed amongst hybrid power system which configures with integrating distributed renewable sources and the backup diesel generator that highly efficient and reliable in the remote areas.

Currently, about 55.41 % of rural areas electrified by REB and cooperative organization PBS, whereas 5.05 million households connected to the grid. Yet 45 % of rural areas not electrified by REB which government owned company, but IDCOL and others POs working together to achieve Millennium Development Goad (MDG) and "Vision 2021" simultaneously, about 94 % households decreases about 1.7 liters of fuel (kerosene) consumptions compare to those not connected to the grid, average 90,000 households connected to the grid. During summer, the number of new households slightly increased to 300,000, and to achieve 100 % of electrification about 450,000 new households need to connect to the grid by 2018. By the successful SHS program along other biomass integration, and enrichment of electric power generation Bangladesh has achieved almost 11000 MW electricity by 2014, but still 40 % of population living without access to electricity.

VIII. REFERENCES

[1] IEA, "Addressing the Electricity Access Gap," World Energy Outlook 2009, Paris, 2010.

[2] UNDP, "Human Development Report," 2008. [Online]. Available: http://hdrstats.undp.org/indicators/211.html. [Accessed 29 feb 2016].

[3] H. K. Alimul, R. Anisur and M. Moniruzzaman, "Source Management of A Hybrid DC Micro Grid in Rural Area of Bangladesh," International Conference Materialsm electronics and information engineering, ISBN 978-984-33-8940--4, 2015.

[4] H. Najmul and K. D. Barun, ""Analysis of cost,Energy and CO2 Emission of Solar Home Systems in Bangladesh," International Journal of Renewable Energy Research , 2012.

[5] BD-Research, "Electricity Senario in Bangladesh," 2012. [Online]. Available: ⟨http://www.bdresearch.org.bd/home/attachments/article/799/Electricity%20Scenario%20in%20Bangladesh.pdf. [Accessed 28 Feb 2016].

[6] M. Mondol, W. Boie and M. Denich, "Future demand scenarios of Bangladesh Power Sector," Energy Policy Report 38, 2010.

[7] H. Ahsan and C. Supachart, "Utilization of Solar and Biomass for Rural Electrification in Bangladesh," in *International Conference and Utility Exhibition* , Pattaya, Thailand , 2014.

[8] Regional Energy Security for South Asia: Regional Report , "South Asian Regional Initiative for Energy Integration," 2014. [Online]. Available: http://www.sari-energy.org/. [Accessed 30 Oct 2015].

[9] Asian Development Bank, "Key Indicators for Asia and the Pacific," Asian Developlment Bank Report, 2011.

[10] JIKA, "Bangladesh Power System Master Plan (PSMP)," Tokyo Electric Power Co. Ltd., Tokyo, 2010.

[11] BBS, "Statistical Yearbook of Bangladesh," Bangladesh Bureau of Statistics, Goverment of Bangaldesh, Dhaka, 2003.

[12] BPDB, "Power Generation Report," Bangladesh Power Developmenet Board , http://www.bpdb.gov.bd, 2013.

[13] IAEA, "Country Power Profile Edition,," Available: http://www-pub.iaea.org/, 2013, [Accessed on 27 June, 2015].

[14] L. Chanda and G. Hossain, "A green Economy in the Context of Sustainable development and proverty Eradication: What are the IMplications for Bangladesh?," *Journal of Economics and Sustainable Development,* vol. 5, no. 3, pp. 119-131, 2014.

[15] R. Plunkett, A. Newton and B. J. Wagenhauser, Bangaldesh, Victoria, Autralia : Lonely Planet Publications Pty Ltd. , 2000.

[16] N. Hosnay, "Acquisition of Sustainable Economic Growth through Proper Utilization of Renewable Energy Sources – A Study on Various Aspects, Challenges

andProspects of RE in Bangladesh," NUB, ET-P11, Dhaka , 2013.

[17] Generation-Report, "Owner Wise Daily Generation Report," 2014. [Online]. Available: http://www.bpdb.gov.bd/bpdb/index.php?option=com_content&view=article&id=193&Iption=com_content&view=article&id=193&I. [Accessed 12 Dec 2016].

[18] A. Khairul and A. Husnain, "Power Crisis & Its Solution through Renewable Energy in Bangladesh Cyber Journals: Multidisciplinary," Journals in Science & Technology. Journal of Selected Areas in Renewable and Sustainable Energy , 2011.

[19] Bari,MN; Hall, DO; Lucas, NJD; et. al., "Biomass Energy use at the Ousehold Level in two Villages of Bangladesh: Assessment of field Methods," *Biomass Energy ,* vol. 15, no. 2, p. 171–180, 1998 .

[20] A. Report, "Annual Report of 2012-2013," Bangladesh Power Development Board (BPDB), Dhaka, Bangladesh .

[21] Asif, Islam; Maidul, Islam; Sanchita, Ghose; et al, "A Review on Electricity Generation and Evacuation in Bangladesh," Energy and Power: academic research, 10.5923/j.ep.20150501.02, Dhaka, Bangladesh, 2015.

[22] B. Report-2014, "Daily Power Generation Report-," Bangladesh Power Development Board, Dhaka, Bangladesh, 2014.

[23] H. Gunatilake and D. Ronald-Holst, "Energy Policy Options for sustinable Development in Bangladesh," *ADB Economics Working paper series ,* pp. 9-12, November 2013.

[24] R. Mustafizur, "Electricity Scenario in Bangladesh," Unnayan Onneshan-The Innovators , Dhaka, 2011.

[25] BPDB, "Power Generation Report," angladesh Power Development Board (BPDB), 2015. [Online]. Available: http://www.bpdb.gov.bd/bpdb/. [Accessed 12 Dec 2015].

[26] Power-Division, "Bangladesh Energy Status Report," Power Division. Ministry of Power, Energy and Mineral Resources. Government of the Peoples Republic of the Bangladesh, 2014. [Online]. Available: ttp://www.powerdivision.gov.bd/user/index. [Accessed 12 Dec 2015].

[27] Annual-Report, "Power Grid Company of Bangladesh (PGCB) 2012-2013," PGBC, Dhaka, Bangladesh , 2014.

[28] D. Palit, "Solar energy programs for rural electrification: Experiences and lessons," *Elsvier: Energy for sustaiable development ,* no. 17, p. 270–279 , 2013.

[29] B. Douglas and F. Gerald, "Rural Electrification in the Development World: a Summery of Lessons from Successful programs," World Bank Energy Sector Management Assistance Programme (ESMAP) , Washington DC, 2004.

[30] D. Palit and A. Chaurey, "Off-grid rural electrification experiences from South Asia: Status and Best Practice," *Energy for Sustainable Development,* pp. 266-267, December 2011.

[31] W. Bank, "Financing for Rural Electrification and Renewable Energy Development Project: Bangladesh (Project Paper Number 64347-BD)," Word Bank , Washington DC, 2010.

[32] BBS, Report of the Household Income & Expenditure Survey, Bangladesh Bureau of Statistics: Dhaka, Bangladesh , 2010.

[33] Power-Division, "Bangladesh Power Sector: An Overview," Bangladesh Power Development Board , September 2015. [Online]. Available: http://www.bpdb.gov.bd/bpdb/. [Accessed 12 Feb 2016].

[34] C. Paul, "Infrastructure, rural electrification and development.," *Energy for Development ,* no. 15, pp. 304-312, 2011.

[35] M. Mahedi, "Electricity Consumption and Economic Growth," *Global Journal of Management and Business Research,* vol. 12, no. 11, 2012.

[36] SREP-Bangladesh, "Scaling Up Renewable Energy in Low Income Countries (SREP): Investment Plan for Bangladesh," Sustainable & Renewable Energy Development Authority , Dhaka, Bangladesh , 2015.

[37] M. Martinez Solaiman , "Inter Press Service," NewS Agency , 08 July 20015. [Online]. Available: http://www.ipsnews.net/2015/05/opinion-clean-energy-access-a-major-sustainable-development-goal/. [Accessed 8 07 2015].

[38] World Bank , "Designing Sustainable Off-Grid Rural Electrification Projects:," The World Bank, Washington DC, USA , 2008.

[39] I. AKM Sardul, I. Mazharul and R. Tazmilur, "Effective renewable energy activities in Bangladesh," *Renewable Energy,* no. 31, pp. 677-688, 2006.

[40] M. Z. Rahman, "Multitude of progress and unmediated problems of olar PV in Bangladesh," *Renewable and Sustainable Energy Reviews,* no. 15, pp. 466-473, 2012.

[41] M. M. Rahman and J. V. Paatero, "A methodological approach for assessing potential of sustainable agricultural residues for electricity generation: South Asian Prospective," *Biomass and Bio Energy ,* no. 47, pp. 153-163, 2012.

[42] NRECA, "Guides for Electric Cooperative Development and Rural Electrification," NRECA International, Ltd , Washington, DC, USA, 2004.

[43] E. Cecelski, "[10]. Cecelski,E, "Enabling equitable access to rural electrification: urrent thinking and major activities in Energy," World Bank, Washington DC, 2000.

[44] IEG-Report, "Rural Electrification and Rnewable Energy Development," Workd Bank, Dhaak, Bangladesh , 2014.

[45] PRODUSE, "The Impact of Electricity Access on Economic Development: A literature Review," Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Frankfurt, Germnay, 2013.

[46] IDCOL, "Renewable Energy Status in Bangladesh," Infrastructure Development Company Limited , 2014. [Online]. Available:

http://www.idcol.org/prjshsm2004.php. [Accessed 12 Dec 2016].

[47] BBS, "Statistical yearbook of Bangladesh 2008," Bangladesh Bureau of Statistics; 2009, Dhaka, Bangladesh , 2009.

[48] M. Islam, M. Islam and M. Beg, "Renewable energy resources and technologies practice in Bangladesh.," *Renewable Sustainable Energy Rev ,* vol. 12, p. 299–343, 2008.

[49] A. Huda, A. Mekhilef and A. Ahsan, "Biomass energy in Bangladesh: Current status and prospects," *Renewable and Sustainable Energy Reviews,* vol. 30, p. 504–517, 2015.

[50] M. Motin, M. Zaman and M. Sheikh, "Energy efficient modelling of solar wind hybrid power system for a tourist island," *Int J Adv Renew Energy Res (IJARER),* vol. 1, no. 1, 2013.

[51] Hasan, AM; Khan, MF; Dey, A; et al, "Feasibility study on the available renewable sources in the island of Sandwip, Bangladesh for generation tion of electricity," *In: Proceedings of the international conference on developments in renewable energy technology (ICDRET),* p. 1–4, 2012.

[52] PSMP, "Power System Master plan Update," Ministry of Power, Energy and Mineral Resources, Dhaka, Bangladesh , 2006.

[53] R. Paleta, A. Pina and C. Silva, "Remote autonomous energy systems project: towards sustainability in developing countries.," *Energy,* vol. 48, no. 1, pp. 431-9, 2012.

[54] S. Islam, "Photovoltaic Technology for Bangladesh," in *Bangladesh University of Engineering & Technology, Dhaka and Center for Renewable Energy System Technology, Leicestershire*, Infield, 2001.

[55] B. Willis, "Friday Focus: How Bangladesh become the world's biggest off-grid solar user," PV-tech, 05 July 2013. [Online]. Available: http://www.pv-tech.org/friday_focus/friday_focus_how_bangladesh_became_the_worlds_biggest_domestic_off_grid_pla. [Accessed 22 July 2015].

[56] IDCOL, "Solar Home System Program and Projects," 2014. [Online]. Available: http://idcol.org/home/solar. [Accessed 30 Dec 2015].

[57] BPDB, "Power Divsion of Bangladesh," Bangladesh, Renewable energy in Bangladesh , 2015. [Online]. Available: http://www.powerdivision.gov.bd/user/brec/49/89. [Accessed 02 Feb 2016].

[58] Khandker, S.R; Samad, H.A; Sadeque, Z.K; et al, "Surge in Solar-Powerd Homes - Experience in Off-Grid Rural Bangladeseh," The World Bank, Washington DC, USA, 2014.

[59] M. Islam, "IDCOL Solar Home System Program," 2014. [Online]. Available: https://www.esmap.org/sites/esmap.org/files/ESMAP_SAR_EAP_Renewable_Energy. [Accessed 30 Dec 2015].

[60] Gunther, Bensch; Jochen, Kluve; Peters, Jörg, "Rural Electrifi cation in Rwanda–An Impact Assessment Using Matching Techniques," RUHR Economic Paper , Dec 2010. [Online]. Available: http://en.rwi-essen.de/media/content/pages/publikationen/ruhr-economic-papers/REP_10_231.pdf. [Accessed 01 march 2016].

[61] IBRD-IDA, "Lighting Up Rural Communities in Bangladesh," The World Bank, 15 Jan 2014. [Online]. Available: http://www.worldbank.org/en/news/feature/2014/01/15/lighting-up-rural-communities-in-bangladesh. [Accessed 02 Mar 2016].

[62] ECOWAS, "ECOWAS Renewable Energy and energy efficiency status report," ECOWAS, 2014.

[63] Sarker, M.J; Asare-Bediako, B; Slootweg, J.Gp; et. al, "DC microgrid with distributed generation for rural electrification," in *47th International Conference on Universities Power (UPEC)*, London, 2012.

[64] K. Hannes, "Hidden Resources in Solar Home Systems as the Base for Bottom-Up Grids. Proc. of the Int. Conf. Innovating Energy Access for Remote Areas: Discovering untapped resourc," in *Proc. of the Int.Conf. Innovating Energy Access for Remote Areas: Discovering untapped resources*, Berkeley, USA, 2014 .

[65] OECD/IEA, "Energy for All: Financing Access to the Poor," World Energy Outlook, Paris, France , 2011.

[66] Martina, Schafer; Daniel, Kammen; Noara Kebir; et al, "Innovating Energy Access for Remote Areas: Discovering Untapped Resources," in *Proceedings of the International Conference, University Berkeley* , Berkeley, 2014.