Eco-Friendly Energy Source in Bangladesh

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Global fossil fuel reserves are declining due to differential uses, especially for power generation. Everybody can help to do their bit for the environment by using solar energy. Geographically, Bangladesh is a potential zone for harnessing solar energy. In March 2021, the renewable generation capacity in Bangladesh amounted to 722.592 MW, including 67.6% from solar, 31.84% from hydro, and 0.55% from other energy sources, including wind, biogas, and biomass, where 488.662 MW of power originated from over 6 million installed solar power systems. Concurrently, over 42% of rural people still suffer from a lack of electricity, where solar energy can play a vital role.

Keywords: solar park ; net metering solar rooftop ; solar irrigation ; solar mini-grid

1. Introduction

Energy is the basis for the survival and development of human life and plays a vital role in a nation's national economic growth and security [1]. No country can be able to promote and sustain its development in the absence of the proper use of energy. Any energy imbalance regarding demand and supply can jeopardize the functioning of a nation, mostly in developing countries [2]. As civilization progresses from modern to ultramodern, the world's energy demand is rising [3], which is the primary cause of global energy issues and is assumed to increase by about five times by 2100 [4]. Every moment of the day, researchers are using more and more energy due to technological advancements [5], high demand [6], and, in some cases, extravagant consumption of electrical and electronic gadgets.

Natural gas, coal, and petroleum are generally denoted as fossil fuels [7]. Typically, electricity is generated by the burning of fossil fuels [8], and roughly 75% (three-quarters) [9] of global energy is fossil-based, emitting a lot of greenhouse gases [10] into the atmosphere. Furthermore, it has been estimated that all global fossil fuels will be wholly depleted within a few decades and that these sources are limited and quickly becoming costly and rare [11]. Therefore, many countries are shifting partially to renewable sources to meet their energy needs [12]. According to REN21, by the end of 2019, the world's renewable alternative energy generation capacity reached 2838 GW [13]. Therefore, to deal with the energy challenge, there is no alternative option without renewable energy sources. Renewable energy is an alternative energy that could assist in reducing fossil fuel demand and play a significant role in the country's energy security [14]. In Bangladesh, solar, wind, hydro, and biomass energy are the primary traditional renewable energy sources, and solar energy has the utmost potential among them [15]. For many nations [16], solar energy is the most attractive alternative energy source among all other renewables.

Bangladesh is the world's eigth most populated country, with a population of 165.88 million [17] and a population density of 1278 persons/km^2 [18]. In urban areas, a maximum of 94.1% of the population has access to electricity [19]. However, 79% and 60% of consumers face low voltage supply and load-shedding [20]. Electrification rates have been improving in recent years because of the rapid progress of grid connection and the insertion of various solar energy projects in rural parts of the country. In March 2021, around 6.02 million solar home systems [21] were mounted on Bangladesh's off-grid spaces, benefiting more than 20 million rural people [22].

According to BPDB, the present growth rate of yearly electricity demand is about 10%, which will probably be higher in the future due to population growth, technological and economic advancements, and continual GDP growth [23]. In the fiscal years 2020–21, 67.71% of electricity was generated from domestic sources (60.19% from natural gas, 6.21% from coal, 0.81% from hydro, and 0.20% from other renewables), 22.52% from imported petroleum fuels (21.76% from furnace oil and 0.76% from diesel), and 10.08% of power was imported [24]. The energy used in domestic, industrial, commercial, agricultural, and other sectors was 56.42%, 28.40%, 10.58%, 2.43%, and 2.16%, respectively, in the year 2020–21.

The total electricity generation in 2019–20 was 71,419 GWh (49.45% from the public sector, 41.20% from the private sector, and 9.35% imported), which was only 1.26% higher than the previous year's net generation due to COVID-19 [25].

In 2018–19, the total electricity generation was 70,533 GWh [26], 12.53% higher than the previous year's net generation of 62,678 GWh [27]. The per capita electricity generation in 2019–20 was 426.23 KWh [28]. According to the updated Power Sector Master Plan (PSMP) 2016, the electricity generation capacity requirements in 2021, 2030, and 2041 will be 21,000 MW, 31,000 MW, and 57,000 MW [29] against the demand of 14,500 MW, 27,400 MW, and 51,000 MW [30].

Approximately 770 million people live without access to electrical power, mainly in Africa and Asia [31]. Over the past decade, Bangladesh has been experiencing a significant shortage of electricity [32]. The current energy production in Bangladesh has not satisfied the power requirements in the industrial, agricultural, and residential sectors, which are the leading causes of severe load shading, less production, and food insecurity [33]. Insufficient energy also leads to income losses, decreased capital formation, reduced exports, and slow economic growth [34]. Hence, the energy issue of the country is a hot topic to meet the sustainable energy demand of the future. Therefore, the government needs to continue searching for viable alternative energy sources, and renewables could be an alternative source. Energy is the main driving force for Bangladesh's development and plays a dynamic role in achieving Vision-2021, Vision-2041, and succeeding SDGs [35]. In continuation, the GoB, with other private organizations, is attempting to reach the target and taking the initiative to generate electricity from renewable sources in the future, including solar, wind, biogas and biomass energy, etc.

2. Geographic vs. Photovoltaic Power Potential of Bangladesh

Bangladesh is a single state with low-lying plain land (except the hilly southeast), mainly riverine and densely populated [36], and is a tropical to subtropical country located in Southeast Asia [37]. It covers 20°34′ N to 26°38′ N latitude and 88°01′ E to 92°41′ E longitude [38]. The area of the country is 147,570 sq. km [39] (56,977 sq. miles) and is bordered by India to the east, north, and west, Myanmar to the southeast, and the Bay of Bengal to the south [40]. Bangladesh relishes a significant volume of sunshine [41] and the usage of solar energy continues to grow, whereas the cost of solar equipment continues to decline.

In Bangladesh, due to its geographical position, for most of the year, sunlight is abundant for harnessing solar power [42]. From March to April, extreme solar emission takes place, and minimum radiation is experienced from December to January [5]. The amount of energy available is high, about 4.0 to 6.5 kWh/m^2/day, and the sunny daylight hours fluctuate from 6 to 9 h/day, almost 300 days per annum, excluding cloud, rainfall, and fog, which is enough to meet the sunlight requirement for solar energy [43].

3. Forms of Solar Energy in Bangladesh

In Bangladesh, solar energy is produced in different forms namely, solar parks, solar rooftops, solar irrigation, solar grids (mini-grids, micro-grids, pico-grids, and nano-grids), solar charging stations, solar-powered telecom BTS, solar home systems, solar street lights, and solar drinking water.

Generally, the reliability, safety, performance, and package life of solar PV depend on the design of the plant, the quality of the components used, expertise in installation, and finally, operation and maintenance [44]. Several parameters which affect the forms of solar energy progress are geographical location, weather conditions, land space, high installation costs for poor people, etc. Dust, clouds, and defective/fractured PV cells such as snail tracks, cell crack, hot spots, ethylene vinyl acetate (EVA) discolouration, PV cell fractures, busbar discolouration, bubbles, Si discolouration, etc. also affect the production of solar energy [45]. Improving performance by reducing maintenance and operating costs has turned out to be an important factor in increasing the competitiveness of photovoltaic (PV) systems [46]. Although there are some drawbacks, in the long run, solar energy is green, clean, and eco-friendly.

The solar projects in Bangladesh are divided into three phases such as (i) project completed and running, (ii) project implementation ongoing, and (iii) project under planning. Now, in March 2021, Bangladesh is producing 722.592 MW of power from RE sources, of which 488.662 MW of power originates from over 6 million (6,325,155) installed solar power systems. Concurrently, over 42% of rural people still suffer from a lack of access to electricity [31]. Approximately 569.496 MW with 108 solar systems are under the ongoing implementation phase, and around 1257.813 MW with 21 solar systems are under the planning phase. Some projects (37 systems with a capacity of 200.28 MW) are rejected from the planning phase. After rejection, the continuing net total proposed amount of solar energy (including i, ii, and iii) is 2315.97 MW with 6,325,284 systems.

Various development organizations, including World Bank, along with other private sectors, are working with the government to generate solar energy in Bangladesh. There are approximately 125 stakeholder companies of RE in

Bangladesh, creating one of the world's biggest domestic solar power projects. Among them, BPDB, BREB, IDCOL, MoDMR, RDCD, EGCB, etc., are mentionable and have been engaged in commercializing solar power in rural irrigation, domestic, and commercial sectors.

3.1. Solar Parks

Solar parks, also known as solar farms, are a group of co-located solar power plants [47]. They represent a concentrated area of large-scale solar power generation projects, similar to natural gas-based electricity generation stations [48]. Unlike solar home systems, solar parks are typically made up of ground-fixed solar panels over large areas [49].

To reduce addiction to fossil fuels with the purpose of power generation, the GoB has already started a grid-connected solar-based power generation project named 'solar park' where no battery backup is desired. Currently, 5 systems (capacity 88.4 MW) are running, 11 systems (565.16 MW) are in the ongoing implementation phase, 19 systems (1257 MW) are under planning phase, and 2 systems (200 MW) were rejected from the planning phase. After rejection from the planning phase, the net generation capacity remains at approximately 1910.56 MW.

In Bangladesh, the largest solar park (capacity of 50 MW) was constructed in Gauripur, Mymensingh, with a total of 173,000 solar panels and 332 inverters (to convert the output from direct to alternating current). The plant was constructed by HDFC SinPower Ltd., under BPDB, which supports meeting the government's goal of producing 10% of the country's total electricity using RE by 2021.

Site selection is an important matter for building large-scale solar parks, as Bangladesh is a highly populated country with a limited amount of land. For this reason, the GoB has targeted two categories of land for setting up solar parks, those that are Govt. owned unutilized non-agricultural lands or open spaces and others are privately owned lands. The implementing agencies of solar parks are BPDB, EGCB, NWPGCL, B-R PowerGen, APSCL, and RPCL.

3.2. Solar Rooftop

Solar rooftops are simply the installation of solar panels on the roof of every residential or commercial building and are suitable in both urban and rural areas. Most of the used building's roofs are vacant either fully or partially. Solar rooftops are divided into two categories, simple "rooftop solar (except net metering)" and "net metering rooftop solar" systems. In a "net metering rooftop solar" system, the prosumer (who produces and consumes electricity) will consume electricity first, and the excess amount is sold to neighboring consumers/the grid [50]. This system is also called "swarm electrification".

Net energy metering (NEM) is a bi-directional meter that can calculate electricity in two directions, from the grid to the customer (import) and from the customer to the grid (export). The eligible customers under NEM are classified into three categories, domestic consumers, commercial consumers, and industrial consumers. The customer's electric bill is calculated (in KWh) from the net energy recorded on the meter, i.e., the net energy consumption from the grid minus the energy provided to the grid. After a certain clearing period, the consumer is either compensated or charged for the remaining electricity import or export.

In July 2018, the Government circulated the NEM standard to allocate rooftop solar electricity added to the grid. To progress this, in 2019, the GoB, SREDA, and SOLshare commenced a test scheme that connected electricity to new families. Furthermore, Grameen Shakti and SOLshare have been mounting peer-to-peer electricity exchange networks [51].

The GoB of Bangladesh has already fulfilled the target of installing 116 systems (capacity 39.53 MW) of decentralized Rooftop Solar Except Net Metering and 1270 systems (capacity 23.027 MW) of Net Metering Rooftop Solar. The government is also encouraging industries to set up solar PV to balance a portion of their energy demand from rooftop solar energy.

3.3. Solar Irrigation

Bangladesh is an agro-based country, and agriculture is one of the major sectors behind the economic growth of the country [52]. Approximately two-thirds of the total population is directly or indirectly involved in agriculture [53]. In 2019, the share of agriculture in the GDP was 13.32% [54]. Because of the tropical to sub-tropical location of the country, irrigation plays a vital role in agriculture [55]. Currently, 1.34 million diesel driven water pumps are running for irrigation purposes, and spending on petroleum costs more than USD 1 billion yearly [56]. Solar-based irrigation is cheap and more eco-friendly than conventional diesel-based irrigation systems [57]. It enables farmers to improve crop yields and can ensure food security. That is why the GoB has devised a plan to install solar-based irrigation to reduce the fuel cost as well as to

reduce greenhouse gas emissions [58]. It is noted that floods have occurred more frequently in Bangladesh [59] during the monsoon season, which could affect the safety and performance of solar PV. To avoid the flood risk, solar components should be installed above the flood water level.

In Bangladesh, approximately 6000 farmers now trust solar irrigation pumps, which are eco-friendly, greener, cleaner, and cheaper than diesel-based pumps. Already, the country has installed 2014 solar irrigation pumps, which have a combined electricity generation capacity of 44.338 MW per hour, and approximately 96 pumps with a capacity of 3.796 MW are under the ongoing implementation phase.

3.4. Solar Mini-Grids, Solar Micro-Grids, Solar Nano-Grids, and Solar Pico-Grids

Though SHSs are successful in rural and remote areas where grid connection is not possible, the demand is more focused on grid-like quality power to run fans, fridges, small shops, small manufacturing systems, and small and medium-sized enterprises, i.e., rice mills, oil mills, spices mill, etc., which enforces the need to discover a reliable electricity system. Moreover, poor people use electricity for lighting purposes only, but middle-income people have more demand for operating fridges, fans, televisions, and charging batteries [60]. That is why the GoB has attempted to expand solar mini-grid, micro-grid, nano-grid, and pico-grid projects that provide electricity to domestic and mini-commercial users to encourage commercial activities in remote locations. The definitions for solar mini-grids, micro-grids.

In Monpura island of Bangladesh, the SREDA, UNDP, and the GEF have successfully installed solar mini-grids under IDCOL's mini-grid projects, and about 1199 households are experiencing this electricity [61]. The token snapshot of the solar mini-grid is shown in Figure S4 [61].

So far, 27 solar mini-grids and 2 solar nano-grids with a cumulative capacity of 5.656 MW and 0.001 MW have been installed and are currently running, and micro-grid and pico-grid projects are planned for the future. Twenty-six mini-grids with a cumulative generation capacity of 5 MW are being financed by IDCOL for approximately 16,000 beneficiaries in rural Bangladesh, also contributing an estimated 29,300 tons of CO_2 reduction during the project lifetime [62]. Although BPDB has installed the largest solar mini-grid project in south Asia, there is also a 650kW project known as the solar mini-grid project at Sullah in the Sunamganj district, financed by the Climate Change Trust Fund (CCTF).

3.5. Solar Charging Stations

In Bangladesh, there are a lot of environmentally friendly, battery-operated, and energy efficient three-wheelers, locally called Easy-bikes/Auto-rikshaw [63]. Most of them are regularly charged dishonestly from the 11 KV grid-connected electricity networks. Solar charging stations are an alternative to decrease the burden on grid electricity. The government has already installed 14 solar charging stations with a cumulative capacity of 0.282 MW, and more charging stations are on their way to be set up all over the country.

3.6. Solar Powered Telecom BTS

A solar-powered telecom system is a system of providing electricity to telecommunication systems in remote areas that are far from the national grid, for example, chars and bars of the river, hilltops, coastal/offshore areas, etc., where electricity is not available or where it is neither possible nor viable to connect new power lines [64]. In remote areas, solar-powered telecom systems allow rural people to access solar power to charge their batteries and use mobile phones, TVs, and radios [65].

In Bangladesh, more than one-fourth of the rural population lives without grid electricity [66]. In rural, remote, hilly, or char (river bar) areas where grid electricity is insufficient or poor people are not capable of taking grid lines, solar energy is the best option to charge their mobile phones.

3.7. Solar Home Systems (SHS)

Solar home systems (SHSs) are globally recognized photovoltaic systems that are used to meet the demand for electricity, especially for rural off-grid households [67]. Currently, students can study at nighttime, village shops can open for a long time at night, and people can charge and access mobile phones at all times in rural Bangladesh due to the installation of solar home systems [68]. In 2003, with the assistance of the World Bank, IDCOL launched the SHS project with the aim of offering finance to several partner organizations for offering loans and collecting installments from customers who are not capable of installing solar panels with self-finance [67]. The main objective of installing SHS is to provide clean and green electricity to off-grid rural households with the aim of achieving the vision for 2021 with a goal of 100% electrification in Bangladesh by 2020 [42].

With a view to developing the biggest off-grid RE platform in the world, the GoB has already installed around 6 million (6,023,631) SHSs in the off-grid zones of Bangladesh in July 2020, and approximately 20 million rural people have benefited from these SHSs, roughly one-eighth of the total population [22]. The cumulative generation capacity of these SHS is close to 262.55 MW.

As the installation of SHS is costly, it becomes commercially competitive at an early stage [69]. However, now it is gradually becoming popular in remote areas due to subsidizing schemes and favorable policies undertaken by the government and other stakeholders such as BREB, IDCOL, GIZ, MoDMR, RDCD, etc. where IDCOL and MoDMR have the largest share. Approximately 70,000 jobs have been opened through SHS projects, and the country is saving approximately USD 225 million, which substitutes 180,000 tons of kerosene every year [70]. Previously, rural people used conventional kerosene lamps at night, but now they no longer have to rely on kerosene and polluting firewood. Girls and boys can now progress their literacy levels by studying at night.

3.8. Solar Street Light

Solar street light is a solar-based lighting system with a view to lighting the road. These lights are independent utility grids of non-polluting environmentally friendly electricity sources for both urban as well as rural off-grid areas and hold minimum operation costs. Currently, many countries are using smart solar-powered street lighting, such as Brazil [71], Japan, etc. [72]. In Bangladesh, a total of 296,061 solar street lights with a capacity of 16.7 MW have been installed by MoCHTA and MoDMR. Several other private organizations also installed solar street lights, which are not included here.

3.9. Solar Drinking Water

In the southern region of Bangladesh, drinking water is scarce due to saline water intrusion from the Bay of Bengal. In the northern high altitude and southern coastal portion of Bangladesh, solar-based water desalination units have high potential. In Bangladesh, a total of 296,061 solar drinking water systems with a capacity of 0.095 MW have been installed.

Furthermore, the GoB have taken initiative for the installation of approximately 1140 solar-based water desalination units to ensure pure drinking water, which will provide safe drinking water to roughly 30,000 people in 16 seaside saline-prone districts of Bangladesh [73].

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