Current Scenario of Solar Energy Production in Bangladesh and Future Potentiality

Debesh Biswas Mridul, Abul Kalam Azad, Mithun Kumar Biswas, Anupa Datta, Khan Mohammad Ridwan Ul Risty

Abstract— As a developing country, Bangladesh is undergoing a huge expansion in industrial and commercial infrastructures which is resulting in the acceleration of energy demand exponentially and it will continue in the same trend in the coming future. These growing demands have necessitated the approaches to generate energy from the sustainable resources, not only to meet the energy requirements but also to reduce GWP (Global Warming Potential), decrease CO_2 emissions, and ensure cost effectiveness in the long run. Among all the sustainable resources, solar energy has attracted significant attention. Innumerable researches and developments on solar energy technologies from all over the world are making this more available and affordable. Bangladesh has taken several initiatives to achieve the SDG (Sustainable development Goals), designed by the United Nations. The purpose is to protect the planet and ensure a sustainable future which is propelling to enhance the solar energy productions. This study will help to understand Bangladesh's present conditions of producing solar energy and its huge potentiality in the future, because this is a well-grounded way of generating power and getting rid of polluting & detrimental non-renewable energy resources.

Key Words— Bangladesh, Clean Energy, Concentrated Solar Power, Renewable Energy, Photovoltaic, CSP, Solar Power, Sustainable Development Goal.

1 Introduction

UTILIZATION of energy is a measure of a country's wealth and standard of living (Esen & Bayrak, 2017). Bangladesh is a developing country and the economy is highly depending on the manufacturing industries (Raihan, Lemma, Khondker, & Ferdous, 2017) (Ministry of Finance, Bangladesh, 2017). Also according to the World Bank, Bangladesh has had a remarkable growth in agriculture which helped in poverty reduction in Bangladesh since 2000 (World Bank, 2016). So the accumulated demand for energy is rapidly increasing as a result of agricultural, technological and industrial growth. Bangladesh will experience an acute energy crisis in the near future (Liza, Akhter, Shahibuzzaman, & Islam, 2020), current energy supplies are unlikely to fulfill power needs. But, on the other hand, energy generation from fossil fuels, i.e. Coal, Furnace Oil, Petroleum, Natural Gas etc. are not the right choices due to their scarcity, unstable international markets, and negative environmental and health impacts (Krautkraemer, 1998) (Kotcher, Maibach, & Choi, 2019) (Chmielewski, 1999). As a result, the government is being forced to consider seriously the development of indigenous alternative and renewable energy sources. Moreover, to achieve the goal of sustainable development, Environmental friendly renewable energy sources must be created and popularized. Clean environment, energy independence, new employment opportunities, and improved living conditions in rural areas resulting in a reduction in mass migration to urban areas are all additional incentives for the promotion of such energy technologies, especially in developing countries like Bangladesh (Mirza, Maroto-Valer, & Ahmad, 2003). According to the SDG7, Bangladesh has already adopted several measures to achieve yielding clean energy, and in 2020 the stake was 3.49% in the total energy consumption (SDG Tracker, Bangladesh, 2020) (Katekar, Deshmukh, & Elsheikh, 2020). There are many means of clean energy; Solar Energy, Wind Energy, Hydro Energy, Nuclear Energy etc. are the main sources of producing clean energy. Among them Solar energy has a huge theoretical potentiality (Demirtas, 2013). Several studies have shown that it is possible to fulfil the global energy demand by using solar energy as it is possible to avail freely from nature with almost no cost (Kannan & Vakeesan, 2016). As a country in the semi-tropical region, Bangladesh has an opportunity of having abundant sunlight all the year round which can be converted into electricity (Deb, Bhuiyan, & Nasir, 2013). The current scenario and future potentiality of using solar energy in Bangladesh are summarized in this paper.

2 Geographic Profile of Bangladesh

It is important to understand the geographical position of Bangladesh. Bangladesh's latitude ranges from 20'34N to 26'38N, and its longitude ranges from 88'01E to 92'41E. Bangladesh has a total area of 147,570 square kilometers. It is bordered on the West, North and East by the Indian states of West Bengal, Assam, Meghalaya and Tripura. Myanmar is the eastern border's southernmost point. The Bay of Bengal has formed the southern border of the region. Fig. 1 depicts the country map. The land border extends for about 4,246 kilometers, 93.9 percent of which is shared with India and 6.1 percent with Myanmar. The coastline stretches more than 580 kilome-

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ters. Bangladesh is divided into seven divisions, which are the main administrative units; Barisal, Chittagong, Dhaka, Khulna, Rajshahi, Sylhet, and Rangpur. Hillocks and hills are restricted to a narrow strip along the southern spur of the Shillong Plateau, the eastern and southern parts of Sylhet district and the Chittagong Hill Tracts in the southeast of the country, which border the Indian states of Tripura and Mizoram as well as Myanmar. Most of the areas of Bangladesh are flat (Chowdhury, 2016). In the Dry season the average sunshine duration is about 7.6 hours a day, and is about 4.7 hours a day in the monsoon season (Deb, Bhuiyan, & Nasir, 2013). Also due to global warming the Heat Index (HI) has risen tremendously (Rajib, Mortuza, Selmi, Ankur, & Rahman, 2011) which is ironic but makes it possible to yield more solar energy.

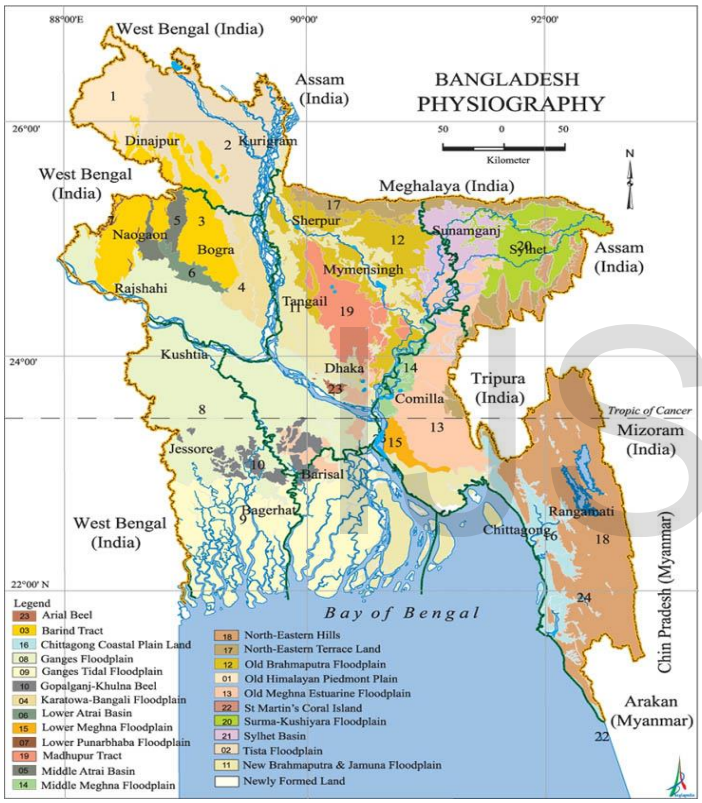

Fig. 1. Map of Bangladesh (Courtesy of Banglapedia)

3 The Current Scenario of Energy Generation

A country's prosperity is determined by the growth of its energy generation capacity (Ahuja & Tatsutani, 2009). Currently, mostly fuel based electricity is being generated in Bangladesh (Uddin, et al., 2018). Natural gas meets nearly 63% of total energy demand. On the other hand, fuels such as oil, coal, and biomass are also meeting demands. The issue is that coal is not being import it from countries like Indonesia, South Africa and India (EIN Presswire, 2020). Natural gas reserves are not in adequate volume, but still it is the biggest resource to generate electricity. With the current consumption rate, it is forecasted that Bangladesh will run out of gas reserves within next 10-12 years (Shetol, Rahman, Sarder, Hossain, & Riday, 2019). In addition to this, Petroleum oil, LPG (Liquid Petroleum gas) and LNG (Liquefied Natural Gas) are also used to meet energy demand but Bangladesh is completely depending on importing those from other countries (Rahman & Mohanty, 2021). Furthermore, the demand for energy is met by importing electricity from India (The Daily Star, 2019). The largest portion of energy is generated by using biomass. Natural gas accounts for about 63% of commercial electricity (with 7% imported LNG) (Unit, 2020). Imported oil accounts for the lion's share of the remainder. Bangladesh has imported about 8.6 million metric tons of crude and refined petroleum products in 2018-19. Coals, in addition with natural gas and crude oil, are mainly used as a fuel in the brick factories and thermal power plants. The total amount of energy consumed is estimated to be around 55 MTOE (mega tons of oil equivalent) (Unit, 2020). Table 1 shows the breakdown of the total consumption in 2018-19. According to the Ministry of Power, Mineral and resources' report, published in 2020, the energy consumption is increasing approximately 6% every year on average. Per capita energy consumption of Bangladesh is 344 kgoe (Kilogram Oil Equivalent) and considering 95% access to electricity, energy generation per capita is 510 kWh and this is much lower than the other South Asian countries (Unit, 2020).

Item	Mtoe
Oil (Crude + Refined) in K ton	8.65
LPG in K ton	0.7
Natural Gas in BCF (Billion Cubic Feet)	22.37
LNG in BCF (Billion Cubic Feet)	2.69
Coal (Imported) in K ton	3.64
Coal (Local) in K ton	0.51
RE (Hydro) in MW	0.17
RE (Solar) in MW	0.27
Electricity (Imported) in MW	0.86
Total Commercial Energy	39.85
Biomass	14.75
Total Primary Energy	54.6

Table 1. Consumed Energy Calculation for 2018-2019. (Unit, 2020)

From Table 1, it is clearly understandable that how much Bangladesh is dependent on the non-renewable resources. Around 15 Mtoe energy came from the biomass incineration which was 27% of total energy. And Bangladesh imported 30.30% from outside sources. Only 0.8% was generated from the sustainable sources. Apart from Solar & Hydro power Bangladesh has installed some other sources too but the stake is almost negligible (Figure 2). Two nuclear power plants are under construction in Rooppur, Pabna which will start producing 1200 MW from 2023 in first phase and another 1200 MW from 2024 (Unit, 2020).

4 The Solar Option

Obviously, the sun is the ultimate source of energy. Solar energy is available everywhere in the planet. Now-a-days, Electricity is generated mainly by using coal, natural gas, oil, nuclear, wind, and hydro power. Solar is superior to fossil fuels

for a variety of reasons. There are two major technologies of harnessing solar energy and they are as follows:

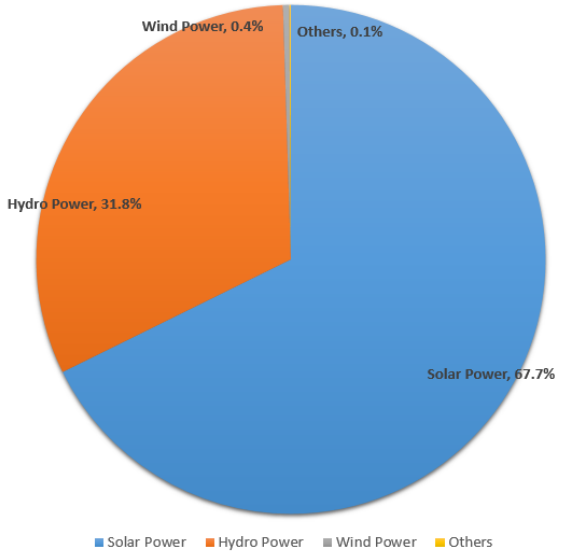

Figure 2: Renewable energy sources of Bangladesh (SREDA, 2020).

(i) Photovoltaic (PV): In this system, solar panels are used, either on rooftops or in ground mounted solar farms, to convert the sunlight directly into electric power.
(ii) Concentrated Solar Power (CSP): It is also known as Concentrated Solar Thermal. In this system solar thermal energy is used to make steam, which is then converted into mechanical power to rotate a turbine for producing electricity (Solar Paces, 2018).
Photovoltaic (PV) does not emit carbon dioxide directly during the energy production and thus does not warm the planet or contribute to climate change (Azarpour, Suhaimi, Zahedi, & Bahadori, 2012). The cost of solar has dropped by 60% in the last few years and it is less expensive than fossil fuels. It is estimated that Solar power costs only 0.10 USD per kWh, and is decreasing remarkably due to the technological advancements (Calderone, 2020) (Evans, 2020). Sunlight can be found almost everywhere in the planet. It is not toxic and does not generate waste. Solar energy does not necessitate massive land destruction or the time-consuming and costly construction of a dam. Solar energy, like any other energy source, has advantages and disadvantages (Lakatos, Hevessy, & Kovács, 2011). However, solar, with its clean abundance, decreasing costs, and zero emissions, outperforms all other energy sources currently on the market. So perhaps solar is the best option. (Gaines, n.d.)

5 Solar Energy Potentials in Bangladesh

Bangladesh is one of those countries where the sun heats the surface all the year round and hence has a large solar power capacity. Bangladesh receives 4–6.5 kWh/m^2 of solar radiation per day, which can produce approximately 1018×10^{18} J of energy (Halder, Paul, Joardder, & Sarker, 2015). Furthermore, the country's recent primary energy consumption of 26.7 Mtoe is equivalent to 1.12×10^{18} J, which accounts for only 0.11% of total solar radiation. In Bangladesh, the solar home system is a more appealing and effective solar technology. It has been revealed that using solar energy for rural and off-grid electrification through solar PV and home systems is more effective. Total installed capacity of SHS has reached 150MW in the year 2013–2014 with 185.185% increase over the previous year. However, the country has almost 234MW electricity generation potential from SHSs. Solar concentrating power is another efficient technology for harnessing solar energy. Grid connected solar PV or mini-grid concept would bring a new dimension in the sector of solar energy utilization. Bangladesh has a potentiality of 50,174 MW grid connected solar PV (Halder, Paul, Joardder, & Sarker, 2015).

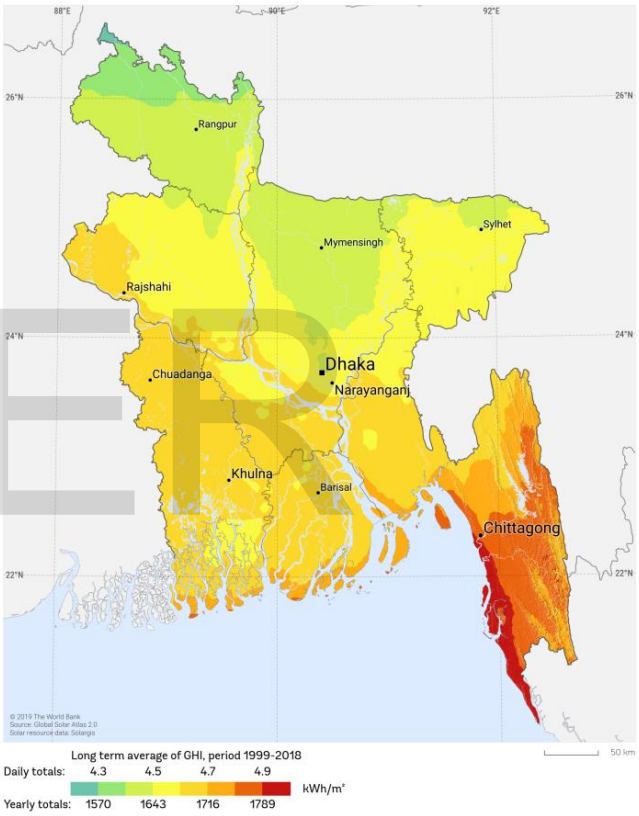

Fig.3. Global horizontal irradiation map of Bangladesh (courtesy of the World Bank Group, http://globalsolaratlas.info)

Study shows that Grid connected Solar PV or Mini-Grid notion can bring a novel extent in solar energy utilization in Bangladesh. As a single source, it can produce 50,174 MW electricity. CSP and SHS have comparatively small but significant potentials too.

Technology	Potential Power
Concentrated solar power (CSP)	100 MW
Grid-connected solar PV	50,174 MW
Solar home system (SHS)	234 MW

Table 2. Solar energy potential in Bangladesh (Halder, Paul, Joardder, & Sarker, 2015)

6 CURRENT SOLAR ENERGY APPLICATIONS IN BANGLADESH

There are two ways to use solar energy. The first is photovoltaic, while the second is solar thermal power. Photovoltaic technology is currently the most popular in Bangladesh. Bangladesh has one of the most extensive domestic solar energy programs in the world. The World Bank and other development organizations, as well as the private sectors, are collaborating with the government to bring affordable, solar-powered electricity to the areas where the traditional grid is inaccessible. Small-scale solar home systems now power over 4 million households and approximately 20 million people in rural areas, accounting for roughly one-eighth of the country's population (Hutt, 2020). Solar energy is the most widely dispersed form of energy. Every single unit household, as well as every commercial or industrial consumer, can use solar energy to generate electricity. Table 3 shows SREDA's road map for the development of the solar energy sectors from the Year 2017 to 2020 (SREDA, 2020).

Program	2017	2020
Solar park	3MW	700MW
Solar home system	205MW	252MW
Solar mini-grid/micro-grid/nano-grid	2.69MW	7MW
Solar irrigation	14MW	46MW
Rooftop solar program-net metering	0MW	600MW
Rooftop solar program-others (including new connection)	30MW	50MW
Solar drinking water system	1.6MW	6MW
Solar power telecoms tower	8MW	15MW
Solar street light	2.3MW	5MW
Total	266.59MW	1681MW

Table 3. Solar Energy Sectors of the Year 2020.

Since 2016, floating solar panels on water bodies have seen rapid growth in various countries due to benefits such as higher efficiency and land savings. Bangladesh has an estimated 150,000 hectares of ponds. Solar panels covering up to a third of each pond can give a total power generation of 15,000MW. Bangladesh has a large number of shallow water bodies such as bills, haors, and baors. The government has taken steps to establish sanctuaries for native fish and other aquatic animals. If 10% of their land can be declared a sanctuary, that portion can be effectively leased out for a 25,000MW floating solar system. (Alam, 2020) Though photovoltaic (PV) is widely used in Bangladesh, there is a significant opportunity in concentrated solar power (CSP) technology. CSP has already been included in the Bangladesh Government's Renewable Energy Policy 2009. Soon it will be cheaper than PV, it would be a better choice to deploy CSP plants for harnessing solar energy on a large scale in order to mitigate Bangladesh's current and future power crisis (Noor & Muneer, 2010). According to SREDA, 36 projects with a total capacity of 2110.56 MW are currently under construction in Bangladesh, among them the largest one is the 50 MW solar plant located at Gauripur in Mymensingh district. Also two large solar projects with a combined capacity of 200 MW are under construction in Bangladesh: Sundarganj in Gaibandha district and Teknaf upazila in Cox's Bazar district.

7 RESEARCH AND DEVELOPMENT (R&D) ACTIVITIES AND INSTITUTIONAL INFRASTRUCTURE

Many institutes, universities, and academic organizations (both public and private) are conducting research and development (R&D) activities on different field of renewable energy technologies. Various organizations and their areas of concern in relation to RET R&D. The following table lists the public bodies that are entirely or partially involved in research in the field of solar energy technologies in Bangladesh and their applications. (Islam, Islam, & Rahman, 2005)

Technology	Related organization	Remarks
Solar photovoltaic balance of systems	Garmeen Shakti, CMES, IFRD	All other device components (such as the charge controller, cable, inverter, and converter) are manufactured locally.
Solar water heaters	RERC, Dhaka University, IFRD, CMES	Manufacturing is possible with a nearby design and fabrication plant.
Solar wood seasoning plant	BFRI	For seasoning timber using solar radiation, a simple, inexpensive, and effective solar kiln has been created. The kiln can be built quickly and easily using locally available materials. In the solar kiln, timbers of various species and dimensions can be seasoned all the year round.
Solar dryer	IFRD, BRRI, BAU	Different types have been created and tested by using materials that are readily available in that region.

Solar cooker-parabolic and Solar cooker-box type	IFRD, ANAN-DO, CMES	IFRD has successfully field-tested its concept, which can easily boil water in a sunny day. Solar cookers of this kind are now available at IFRD for Tk. 450.00 (US$ 9.00). ANANDO also uses imported materials and designs in the production and marketing of its goods. The construction of the IFRD is made from locally sourced raw materials. The cost of making such a cooker is approximately Tk. 800 (US$ 16.00), except the cost of utensils. The cookers are now available for purchase at IFRD.
Solar passive architecture	BCSIR	On the BCSIR campus, a solar house was planned and constructed with the aim of keeping the house warm in the winter and cool in the summer.

Table 4. Solar energy technologies in Bangladesh

*CMES- Center for Mass Education in Science,
*IFRD- Institute of Fuel Research Development,
*RERC- Renewable Energy Research Center,
*BFRI- Bangladesh Forest research Institute,
*BRRI- Bangladesh Rice Research Institute,
*BAU- Bangladesh Agricultural University,
*BCSIR- Bangladesh Council of Scientific and Industrial Research.

Some government agencies and non-governmental organizations (NGOs) have already made many attempts to grow the Renewable Energy sector as a whole, which is outlined in the following paragraphs.

8 GOVERNMENT ORGANIZATIONS

8.1 BPDB's solar electrification project in Chittagong hill tracts:

BPDB (Bangladesh Power Development Board) has completed a Research Project for Solar PV in the Chittagong Hill Tracts Area and is effectively working on a Solar Photovoltaic Project in another three upazilas in the Chittagong Hill Tracts region in order to build various solar photovoltaic applications such as solar home systems, water pumps, vaccine refrigerators, street lamps, and including a centralize power station. The Trustee Management Committee, comprised of local residents, will be in charge of overall scheme oversight and bill collection. (Islam, Islam, & Rahman, 2005)

8.2 REB's solar project:

In 1997, the Rural Electrification Board (REB) completed the first semi-commercial 62 kW Solar Photovoltaic Project. 6000 consumers were electrified by solar home systems during the project's second phase (1999–2004). (Rural Electrification Board web site, n.d.)

8.3 IFRD's project:

Bangladesh Council of Scientific and Industrial Research's Institute of Fuel Research Development (IFRD) (BCSIR). The project's goal is to collect data and information in order to investigate the feasibility of natural solar, wind, and micro-hydro power applications in Bangladesh. (Islam, Islam, & Rahman, 2005)

9 PRIVATE SECTORS & NON-GOVERNMENTAL ORGANIZATIONS (NGO)

9.1 Grameen Shakti's projects in rural areas:

Grameen Shakti was founded in 1996 with the goal of developing and popularizing renewable energy resources. It has received worldwide acclaim for its innovative use of 'micro-credit' to deliver solar home systems in rural areas. Grameen Shakti plans to install 20 small battery charging stations, 20 computer training centers, and 20 multi-service centers powered by solar energy over the next two years. Grameen Shakti has received loans and grants from a variety of bilateral and multilateral development partners, including the GEF (Global Environment Facility), IFC (International Finance Corporation), USAID (United States Agency for International Development), SIDA (Swedish International Development Cooperation Agency), and others. (Islam, Islam, & Rahman, 2005)

9.2 Centre for Mass Education in Science (CMES)'s Program:

CMES has started solar energy-related activities in remote areas of the country. It has conducted research and development on solar cookers, solar water heaters, solar dryers, solar home systems, and so on. It has recently established its 'Solar Lab' to conduct adaptive research on solar PV system accessories such as tube light ballasts, charge controllers, inverters, income-generating appliances such as sewing machines, drilling machines, and so on. (Islam, Islam, & Rahman, 2005)

9.3 Bangladesh Rural Advancement Committee (BRAC)'s Program:

It is the largest Bangladeshi non-government organization, and it has started its solar energy program from 1997. More than 500 solar PV systems and 260 Hot Box cookers have been installed as part of the program. It has two grid-interactive PV systems installed. (Islam, Islam, & Rahman, 2005)

10 Government Policies and Fiscal Incentives

Since 2008, Bangladesh government has taken several policies to familiarize the solar energy generation which are already in action. An institution has been created, SEDA (*Sustainable Energy Development Agency*), which is working as a company and is responsible for providing coordination of sustainable energy planning, including action plans linking with the activities of several agencies and organizations. It also promotes awareness of solar energy technologies. It is also creating market opportunities and support new business models. Apart from these, government exempted charging 15% VAT on Solar energy equipment and established a micro-credit system to provide financial supports for purchasing these equipment. SEDA is in charge of considering and providing subsidies for installation of solar energy projects. Power Division of MPEMR (*Ministry of Power, Energy and Mineral Resources)* and SEDA, in consultation with BERC (*Bangladesh Energy Regulatory Commission*), have created necessary regulatory framework to encourage generation of electricity from renewable energy sources like solar power. (BERC, 2008).

11 Academic Institutions

Several Universities in Bangladesh have been working in the field of solar energy in recent years. For example, United International University's Center for Energy Research has been a leading renewable research and consultancy center in Bangladesh. BRAC University is working with a developing country on a financial and performance analysis of a micro controller-based solar-powered auto rickshaw. Bangladesh University of Engineering and Technology has a solar lab that conducts research activities which are a mix of basic and applied research, as well as the development of renewable energy research in Bangladesh. The Institute of Energy, University of Dhaka is also working on it. Some other universities, such as AIUB and the University of Rajshahi, are also working on solar energy technology. (BRAC University, n.d.) (Bangladesh University of Engineering & Technology, n.d.) (University of Rajshahi, n.d.) (Independent University, Bangladesh, n.d.) (University of Dhaka, n.d.)

12 Conclusion

According to the findings of the above study, solar energy contributes significantly to our energy generation. Through solar thermal and solar photovoltaic (PV) routes, solar energy can be utilized. Solar power is more environmentally friendly compared to the non-renewable sources such as fossil fuels. Solar energy utilization in Canada, Germany, Spain, Australia, China, and France are some of the successful projects. The existence of solar energy policies in these countries resulted in a significant increase in solar power generation. In our country, first and foremost, social awareness should be raised through media awareness programs such as talk shows and seminars. Training programs led by experts from countries well known for their achievements in the solar energy sector can be organized. Many countries, including Denmark, Spain, and Germany, have already declared national policies requiring renewable energy to meet at least 20% of national demand, in accordance Bangladesh has also devised a strategy to meet 5% of the country's energy needs from renewable sources. But apart from these, the Bangladesh government should establish large-scale solar energy manufacturing hubs so that the stake of solar power in the national grid can be increased significantly. Dedicated solar power hubs can be installed for the economic zones rather than include this manufactured electricity in the national grid. Government should encourage heavy industries to install solar panels in their manufacturing plants to decrease the dependency on fossil fuel generated energy. Along with increasing funding to the local researches, the government should also monitor the international research and developments to have immediate access to the more affordable and powerful versions of manufacturing solar energy. So considering the geographical advantages and the necessity of faster transitions, actions taken by Bangladesh are admirable, but more should be done to meet the growing demand for electricity to support ambitious social and economic growth.

Author Contribution

DBM and MKB conceived the presented idea and collected data. DBM, MKB and AKA did the literature review. DBM, MKB, AKA, AD and KMR wrote the manuscript.

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