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Assessment and Way Forward for Bangladesh on SDG-7: Affordable and Clean Energy

Vikrant P. Katekar*,[1], Sandip S. Deshmukh[+], and Ammar H. Elsheikh[#]

Abstract *– In 2019, Bangladesh was one of the world's fastest-growing economies with a GDP growth rate of 7.9%. However, the county is facing challenges such as energy scarcity, widespread poverty, and overpopulation. This article discusses the energy scenario in Bangladesh in terms of energy resources, supply mix, access to electricity and cooking fuels. It describes major issues and challenges, macro and micro initiatives taken by the Government of Bangladesh to attain SDG-7. The manuscript also compares the progress of Bangladesh with other South Asian countries. Finally, the paper recommends some policy interventions to attain SDG-7 as early as possible. This study concludes that Bangladesh is severely facing the problem of energy scarcity to maintain sustainable economic growth. It has been also observed that Bangladesh has a limited focus on renewable energy utilisation. With the huge availability of renewable energy potential, Bangladesh will not only solve the problem of energy scarcity but also save huge expenditure on imports of fossil fuel.*

Keywords *– energy accessibility, energy security, energy supply and demand, renewable energy, sustainable development, SDG.*

1. INTRODUCTION

The Sustainable Development Goals (SDGs) confirm the pathway to achieve a better and more sustainable future for people from every corner of the world. SDGs address global challenges such as poverty, inequality, climate change, environmental degradation, peace, and justice [1]. Table 1 describes 17-SDGs in a concise form, which the world needs to achieve by 2030.

Energy is a driving force to the socio-economic development of every country [2]. Now the world population enormously raised the energy demand; consequently, the world is facing an issue of an energy shortage [3]. SDG-7 ensures access to affordable, reliable, sustainable, and modern energy for all. It would be easily recognised that the attainment of SDG-7 is essential for the attainment of other SDGs, such as SDG-3, 4, 6, 8, 11, and 12 as shown in Figure 1.

Bangladesh is a country located in the north-eastern part of the Indian subcontinent. Figure 2 illustrates a geographic map of Bangladesh [4]. It is a rapidly emerging middle-income country from its independence in 1971. The country is recognized all over the world for dramatically reducing poverty [5].

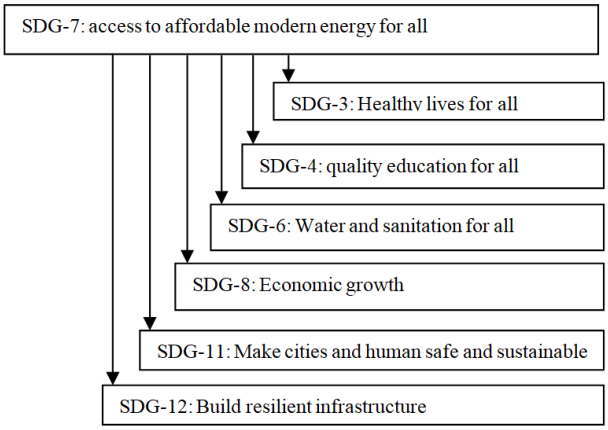

Fig. 1. Interlinking of SDG-7 with other SDGs.

Fig. 2. Country map.

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Table. 1. Sustainable development goals [1].

SDG- 1	End poverty in all its forms everywhere
SDG- 2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
SDG- 3	Ensure healthy lives and promote well-being for all at all ages
SDG- 4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
SDG- 5	Achieve gender equality and empower all women and girls
SDG- 6	Ensure availability and sustainable management of water and sanitation for all
SDG- 7	Ensure access to affordable, reliable, sustainable and modern energy for all
SDG- 8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
SDG- 9	Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation
SDG- 10	Reduce inequality within and among countries
SDG- 11	Make cities and human settlements inclusive, safe, resilient and sustainable
SDG- 12	Ensure sustainable consumption and production patterns
SDG- 13	Take urgent action to combat climate change and its impacts
SDG- 14	Conserve and use the oceans, seas and marine resources for sustainable development
SDG- 15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
SDG- 16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
SDG- 17	Strengthen the means of implementation and revitalise the global partnership for sustainable development

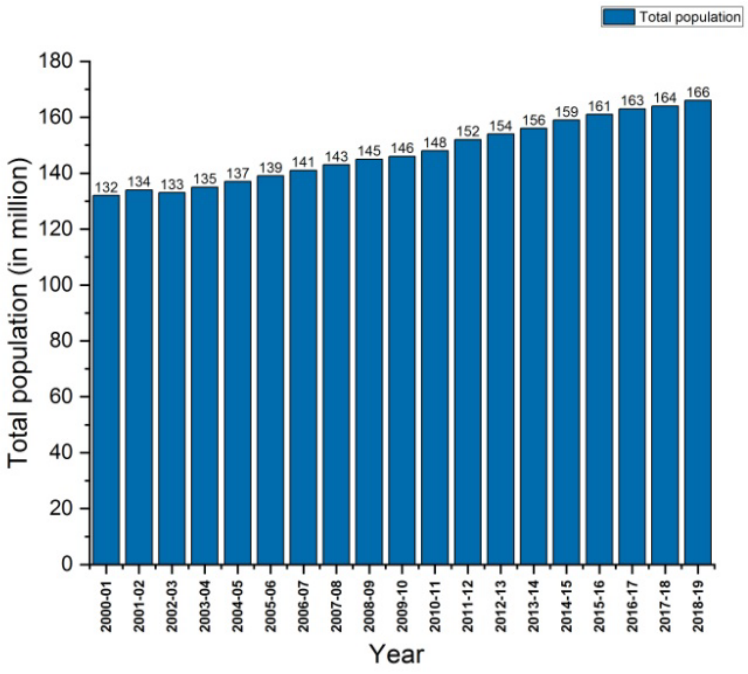

Fig. 3. Population growth [6].

Bangladesh is a densely-populated country, occupying of the geographical area of 147570 square kilometres. As illustrated in Figure 3, the population of the country is growing at a rate of 1.1% per annum [6]. Table 2 shows other statistical details of the country [7].

Bangladesh is a fast progressing country with a constant increase in GDP at an average rate of 6.5% in the last decade (see Figure 4). With rapid growth, the country is facing a scarcity of energy for households, transport, agriculture, and the industrial sector [9].

This study aims to understand the present status of national energy management, future issues, barriers, and efforts required to ensure energy security, sustainability to attain the SDG-7. This paper overviews the current energy scenario, energy accessibility to people, macro and micro-level initiatives taken by the Government of Bangladesh to achieve SDG-7. The manuscript also compares the progress of Bangladesh with other South Asian countries. Finally, the paper recommends some policy interventions to attain SDG-7 as early as possible.

Table 2. Country statistics [8].

Total population (2016)	162952000
Gross national income per capita (PPP international $, 2013)	2810
Life expectancy at birth m/f (years, 2016)	71/74
Total expenditure on health per capita (Intl $, 2014)	88
Total expenditure on health as % of GDP (2014)	2.8

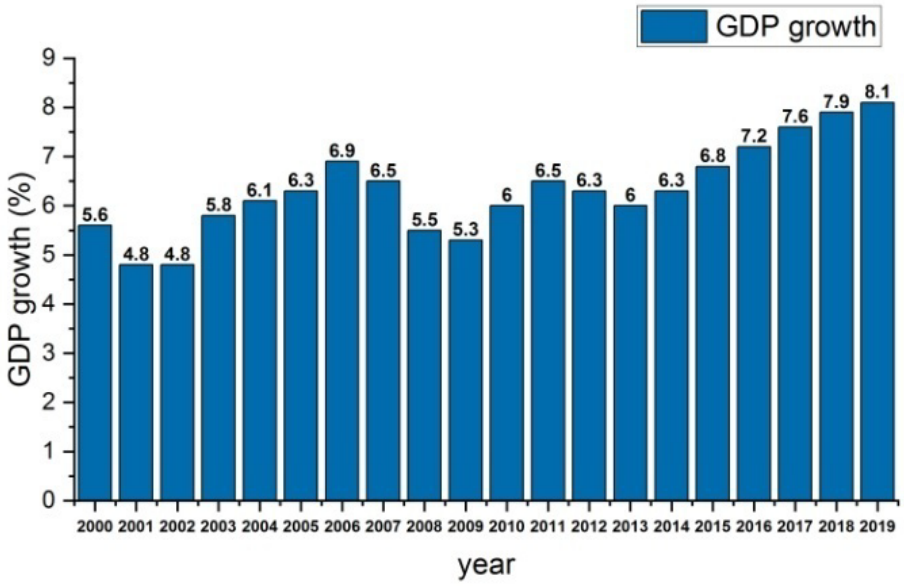

Fig. 4. GDP growth rate [9].

2. METHODOLOGY

Several peer-reviewed research papers of international repute and reports published by various distinguished organizations such as the UN, WHO, UNICEF, IEA, IRENA, IEEJ and Government of Bangladesh have been collected from several websites. They are categorised based on the type of energy sources used for electricity generation, cooking, and national initiatives for energy security, sustainable developments, and policies. All papers and reports are read multiple times, and significant findings have been noted down. Various facts and figures are compared to investigate the progress of Bangladesh on SDG-7, as well as present and future challenges to attain SDG-7. Figure 5 illustrates the numbers of publication/reports referred to accomplish this study.

3. PROGRESS OF BANGLADESH ON SDG

United Nations Sustainable Development Goals (SDGs) aims to end poverty and hunger from the world and to build up a sustainable world. In September 2015, the world accepted the 2030 agenda for SDGs [10]. There are a total of 17 sustainable development goals (SDGs) and 169 targets associated with them. The SDG-7 is associated with energy whose details are given in Table 3 [10].

Bangladesh has to provide clean and economical energy access to all households and businesses, improve the energy efficiency of equipment, reduce the carbon footprint on the environment and develop sustainable technology and infrastructure for energy production and distribution as to align its development with SDG-7 Targets (Table 3).

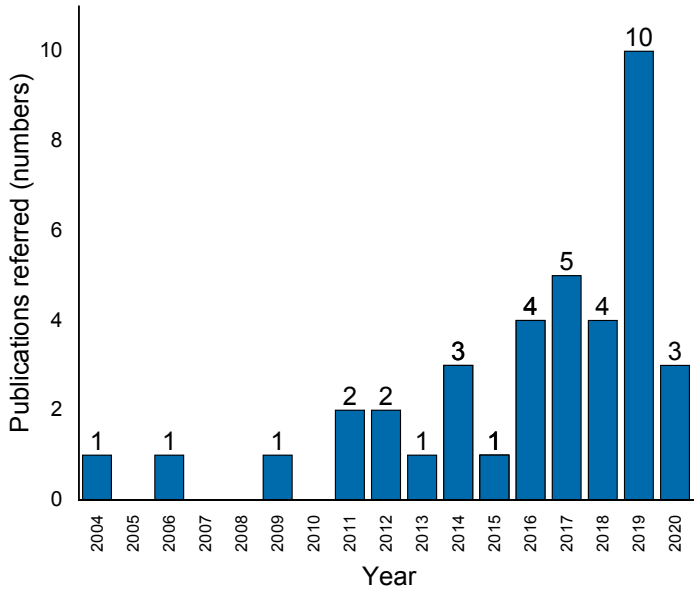

Fig. 5. Numbers of publication/reports referred.

Table 3. Details of Sustainable Development Goal-7 [10]**.**

Goal 7: Affordable and clean energy	
Target 7.1	Make sure worldwide access to reasonably priced, reliable, and contemporary energy services by 2030.
Target 7.2	Significant increase in the share of renewable energy in the universal energy mix by 2030.
Target 7.3	Doubling the global rate of improvement in energy efficiency by 2030.
Target 7.4	Improve worldwide co-operation to make easy access to clean energy research and technology by 2030.
Target 7.5	Expand infrastructure and advancement in technology for supplying modern and sustainable energy services for all in developing countries by 2030.

3.1 Present Energy Sector Scenario

Electricity generation in Bangladesh is highly dependent on fossil fuels. Figure 6 shows that 57.33% of energy has generated by using natural gas, followed by furnace oil and coal. The share of renewable energy is less than 1%. In the year 2019, total net energy generation was 70533 GWh, which is 12.53% higher than the generation in 2018. Out of this 35107 GWh, the energy was generated by the public sector, and 28640 GWh energy was generated by the private sector. In addition to this, 6786 GWh energy was imported from India [11].

3.2 Energy consumption and demand

It is well known that poverty eradication, economic growth, development of sustainable infrastructure, and security depends on energy availability [12]. At the time of independence in 1971, only 3% of people in the country had access to electricity. Year by year, energy access to people is increasing at a rapid rate. Now, the Government of Bangladesh is committed to ensuring access to clean, affordable, and reliable electricity for all by 2021 [13].

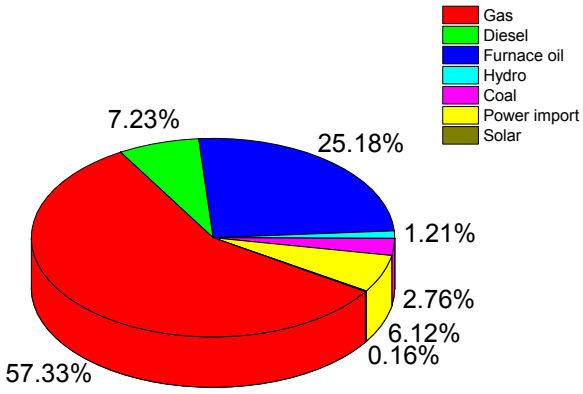

Fig. 6. Primary energy mix [11].

Primary energy mix (Figure 6) shows that most of the primary energy demand is fulfilled by burning natural gas. The current demand for natural gas is above 3200 Million standard cubic feet per day (MMSCFD), with average supply and shortfall of 2740 and 500 MMSCFD respectively. Table 4 illustrates the Bangladesh gas reserve capacity. A total of 26 gas fields are present in the country; out of that 20 fields are in production. Total estimated proven gas consumption is 20.77 trillion cubic feet (TCF), and the recoverable

probable reserve is 6.35 TCF. It is reported that 13.52 TCF gas was produced up to 2015, so only 13.6 TCF of recoverable gas is available [9].

Table 4. Bangladesh gas reserves [9].

Reserve type	Trillion Cubic Feet (TCF)
Gas Initial in Place (GIIP)	39.80
Proven + Probable + Possible (3P)	30.82
Proven + Probable (2P)	27.81
Proven (1P)	20.77
Remaining Recoverable (2P)	11.92
Used (Consumed) as of 30 June 2018	15.90

Figure 7 shows yearly gas production and its future forecast. It is estimated that the natural gas reserve of the country may end in 2026. The government is trying to meet the growing demand of energy by importing liquefied natural gas (LNG). After gas, diesel and coal are mainly used as fuel for energy. Table 5 shows major coalfields and their capacity in the country. Daily coal production is 4000-5000 metric tonnes. Presently country imports 1090940 metric tonne coal, 1090940 metric tonnes crude oil, and 4752607 metric tonnes refined oil to satisfy present energy demand [9].

Table 5. Details of coal mines [9].

Field	Depth of Coal seam (m)	Reserve (Million Metric Tons)	Percentage of total Reserve (%)
Barapukuria	118-510	390	11.81
Phulbari	150-240	572	17.33
Khalislrpir	257-480	685	20.75
Dighipara	328-107	600	18.18
Jamalgong	640-1158	1053	31.90

Figure 8 compares energy consumption in 2014 and its future demand in 2041. During this time frame, it is forecasted that natural gas consumption will decrease from 57% to 38%; however, the demand for oil and coal will significantly increase. The coal demand will increase from 3% to 20% (by more than 560%), and oil demand will increase from 17% to 25%. Another noticeable forecast is that nuclear energy will also come in to picture with 9% of its share in energy production in 2041. Presently, the Government of Bangladesh is in the process of establishing the 2400 MW nuclear power plant. The use of bio-fuel and bio-mass will significantly be reduced from 23% to 3% in 2041 that will bring a significant reduction in domestic sector indoor pollution. But, the share of renewable energy will remain marginal (0.16%) in 2041 [14].

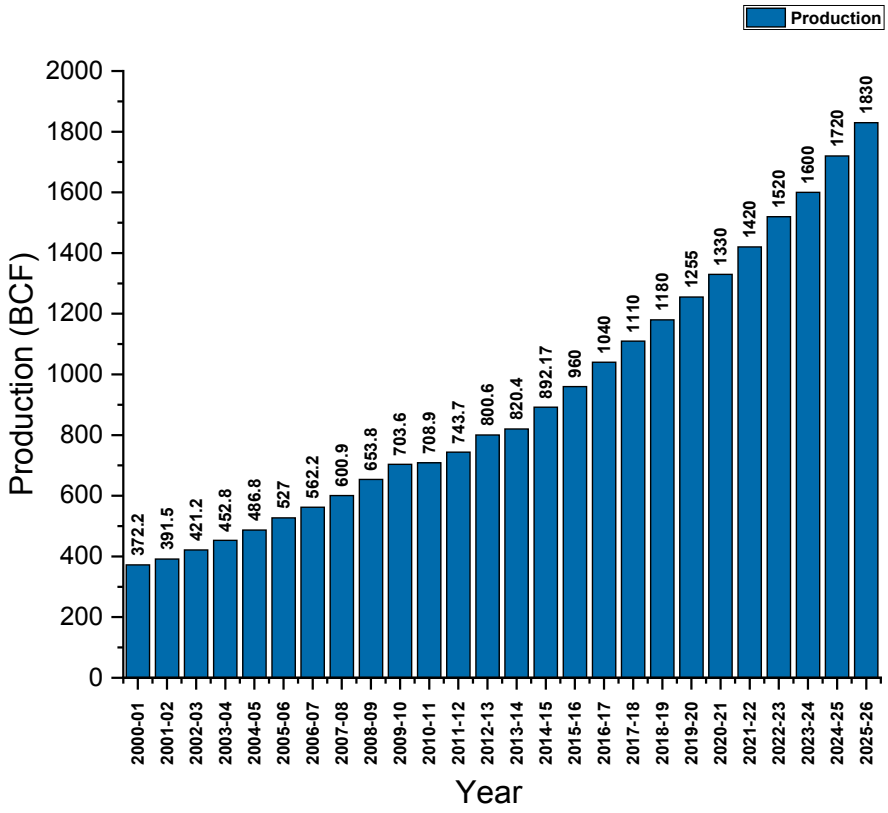

Fig. 7. Yearly gas production rate and its forecast [9].

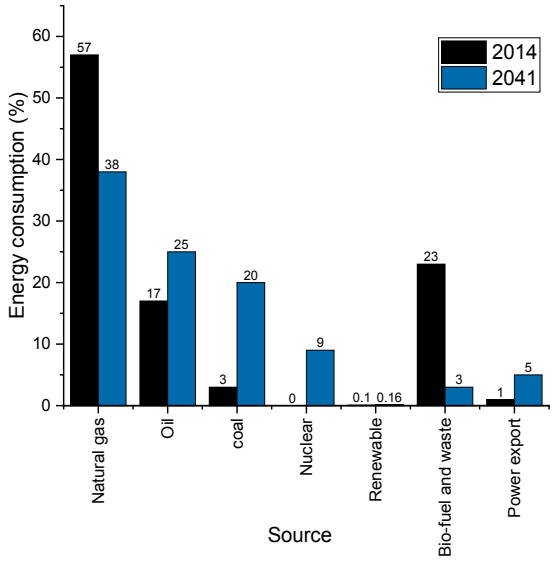

Fig. 8. Primary energy projections [14].

With the mission 'Electricity for all' in 2021, the Government of Bangladesh is meticulously moving towards energy production and distribution, which can be easily identified with a remarkable increase in per capita energy consumption (see Figure 9). In the last two decades, per capita, energy consumption is almost linearly increased from 100 kWh to 325 kWh.

Every year, the country is increasing its electricity generation capacity consistently. Figure 10 illustrates the percentage increase in the energy generation capacity of the country over the preceding years. In the year 2017-18 and 2018-19, energy generation capacity was increased by 15.6% and 17.66% respectively [9].

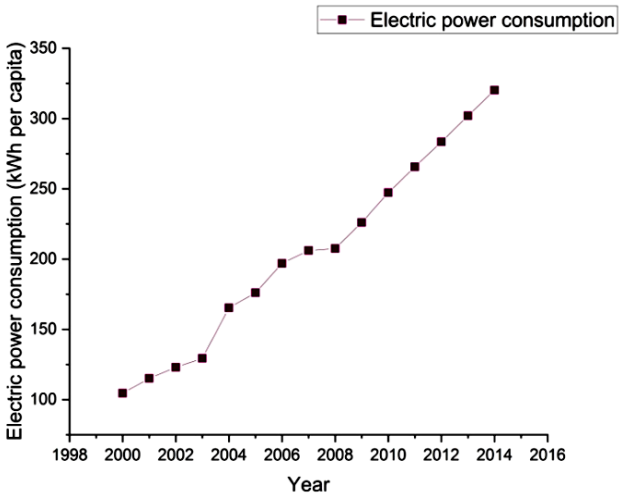

Fig. 9. Electricity consumption per capita [14].

The government of Bangladesh is succeeded to maintain a higher installation capacity than maximum demand. Figure 11 compares installed capacity and maximum demand as on the date. It shows that the installed capacity is greater than the maximum demand of the country, in addition to this, the gap between installed capacity and maximum demand has widened during the past decade [13].

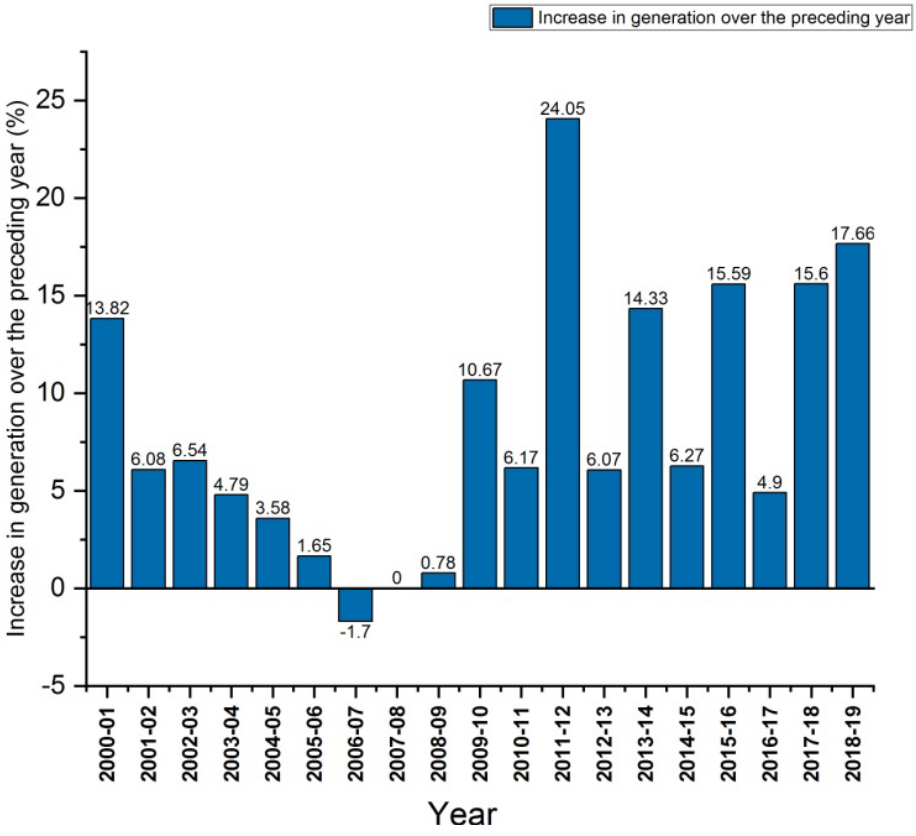

Fig. 10. Increase in a generation capacity [9].

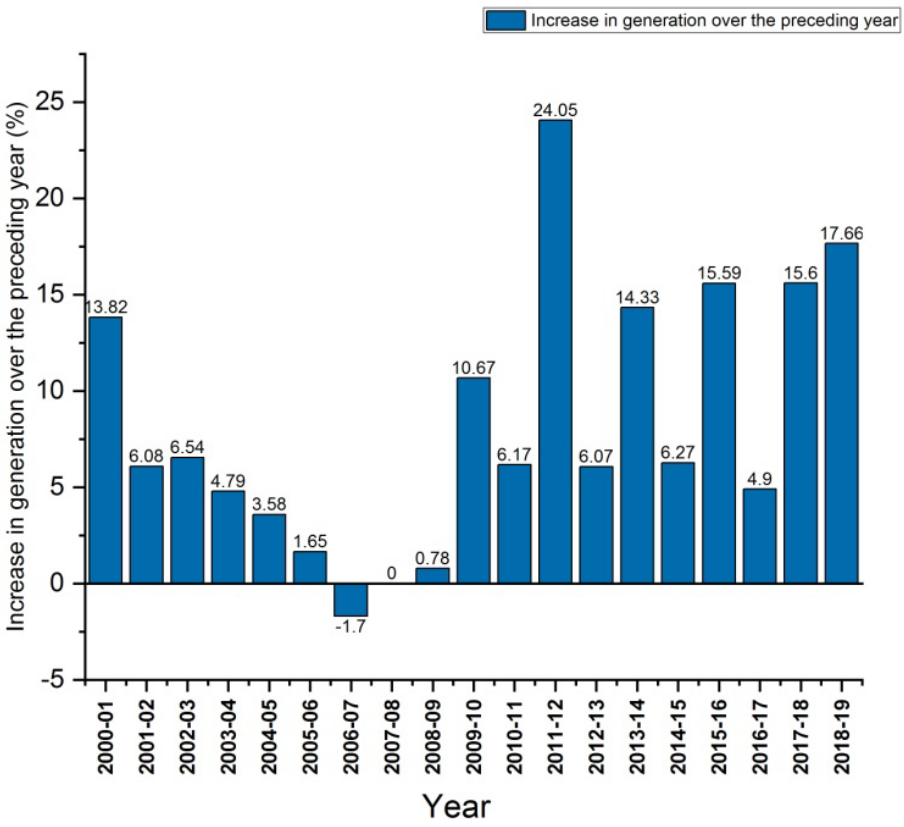

Fig. 11. Installed capacity and maximum demand [13].

Electricity consumption per capita measures the average kilowatt-hours (kWh) of electric power generated by the country per person per year [15]. Per capita, the energy consumption of Bangladesh is less (see Figure 12), and only 84.9% of the population has access to electricity in the country (see Figure 13). Maximum electrification has been done in cities and industrial area. 95% urban and 78.5% rural households are enlightened with electricity as shown in Figure 14. Work on rural electrification is in progress at a rapid rate [13].

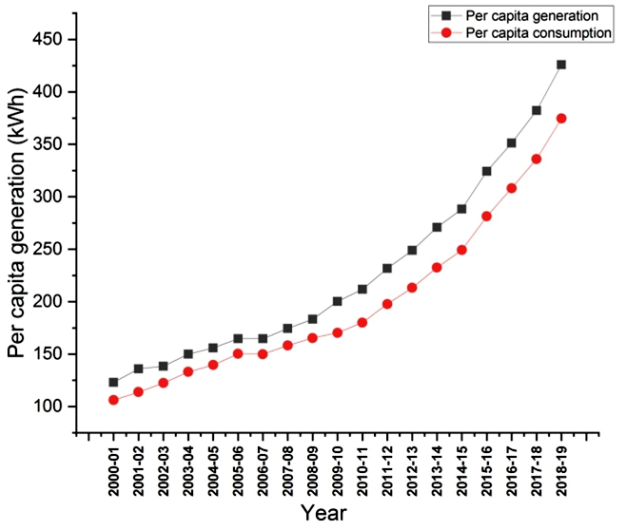

Fig. 12. Per capita energy generation of Bangladesh.

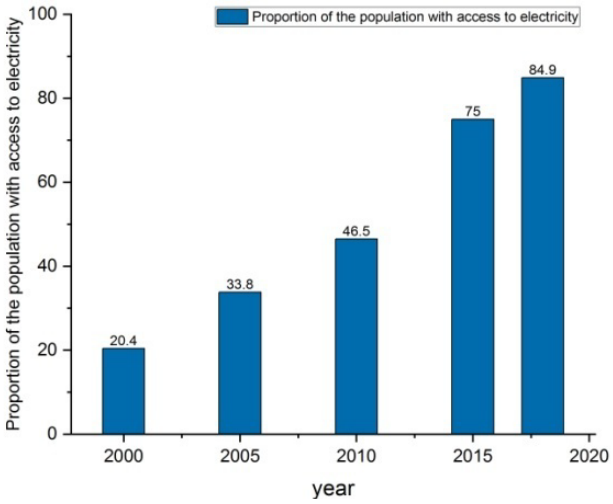

Fig. 13. Population with access to energy [13].

Although the country has installed capacity higher than its present maximum demand (Figure 11), the country is succeeded to provide electricity to only 84.9% of people (Figure 13). The major reasons behind this shortage are actual generation capacity of power plants is less than its rated capacity and distribution losses. Particularly in the rural and coastal areas, the country lacks in energy infrastructure. Figure 15 shows that at present, the country has a 9.12% distribution loss. But it is very remarkable that during the past two decades, there has been a significant reduction in distribution loss

from 26.11% in the year 2000-01 to 9.12% in the year 2018-19 [16].

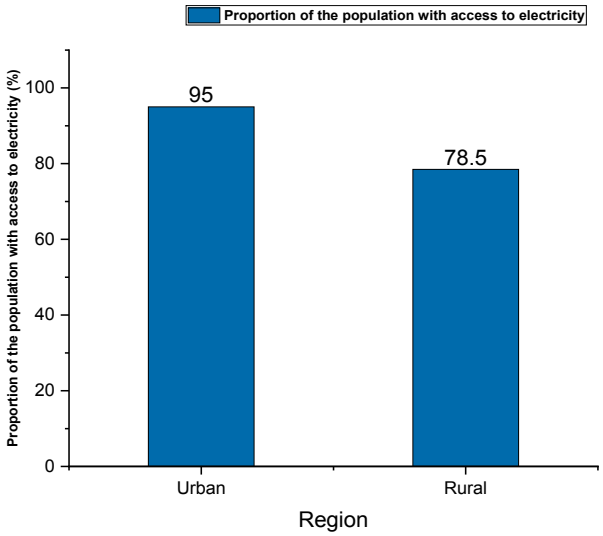

Fig. 14. Population with access to electricity [13].

A country is progressing consistently, the percentage of people with access to electricity is also increasing. Figure 16 shows electricity consumers in the domestic and agricultural sectors. Electricity consumers in the agriculture sector were less and also found to be decreasing from the year 2000-01 to 2004-05; however, later on, consumers in domestic as well as the agriculture sector are increasing consistently. There has been some decrement also noticed from 2015 through 16 to 2016-17, but afterwards, domestic and agriculture consumers are again increasing [16].

A similar trend is also observed for industrial consumers (Figure 17). Small industrial, small commercial and large industrial and commercial electricity consumers are consistently increasing from the year 2004-05. Figure 16 demonstrates that country is progressing in the agriculture and industrial sector; consequently, the GDP of the country is increasing consistently (see Figure 4) [16].

With the rapid and consistent increase in electricity consumption, the demand for fossil fuel is growing significantly [17]. The requirement of natural gas, furnace oil, diesel, and coal is constantly increasing from 2000-01, which is fulfilled by importing these fuels (Figure 18). The country is, therefore, paying heavy fossil fuel import bills, as shown in Figure 19. It shows how expenditure over the fossil fuel of public sector power plants is significantly increasing from the year 2010 [13].

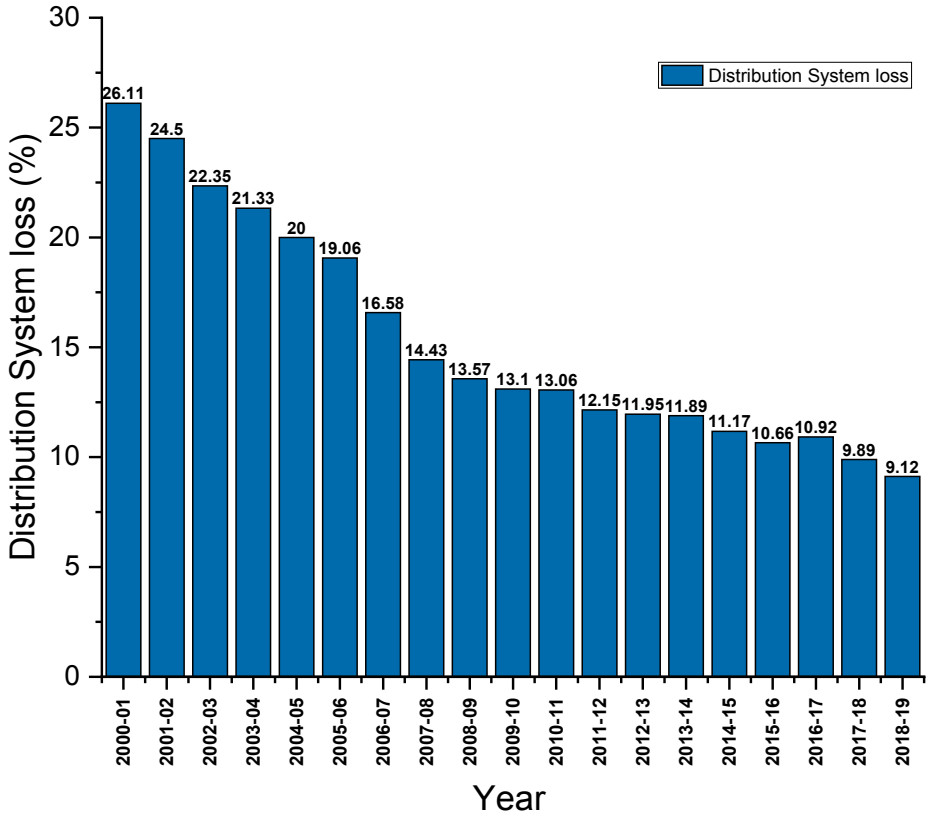

Fig. 15. Distribution system losses [16].

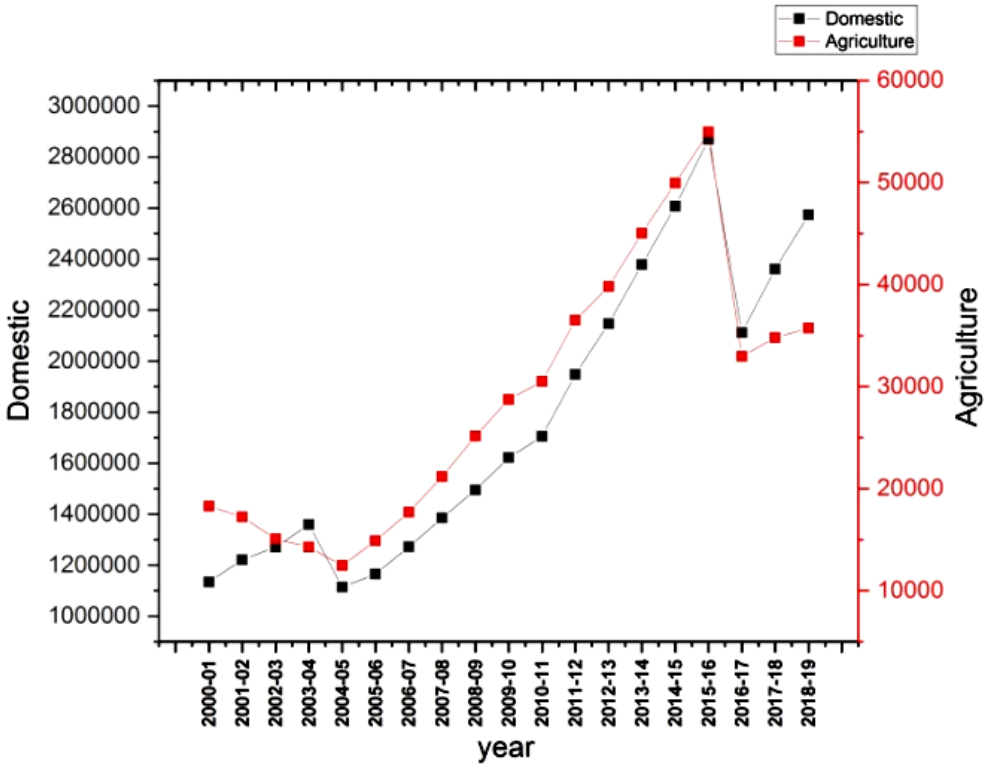

Fig. 16. Electricity consumers in the domestic and agriculture sector [16].

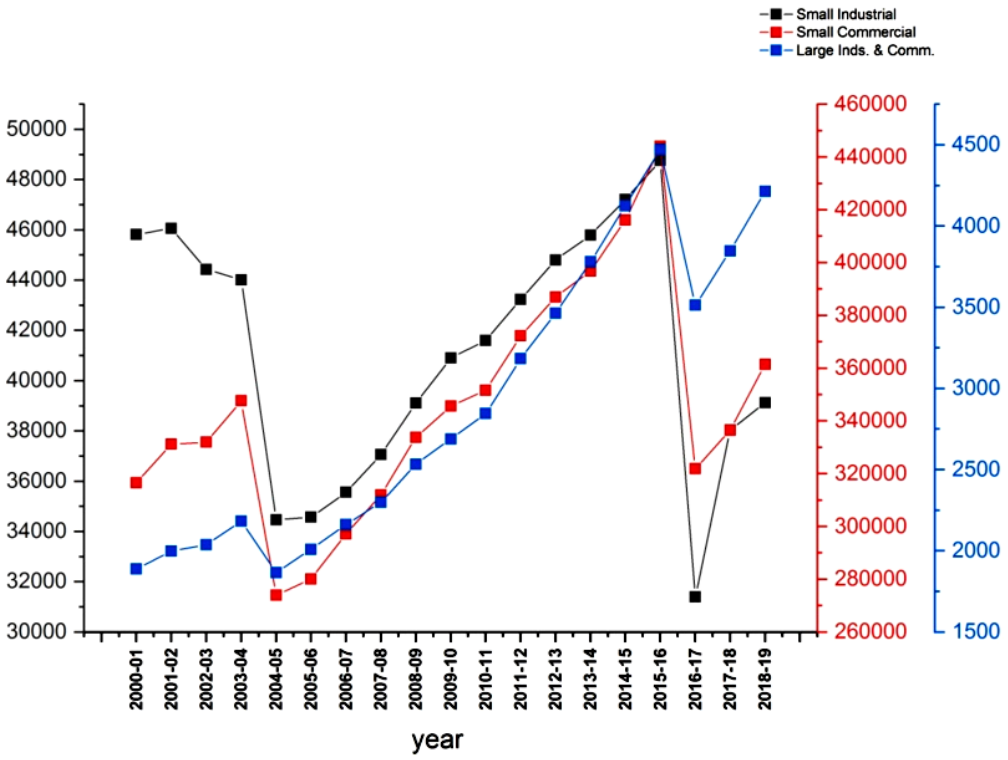

Fig. 17. Electricity consumers in the industrial sector.

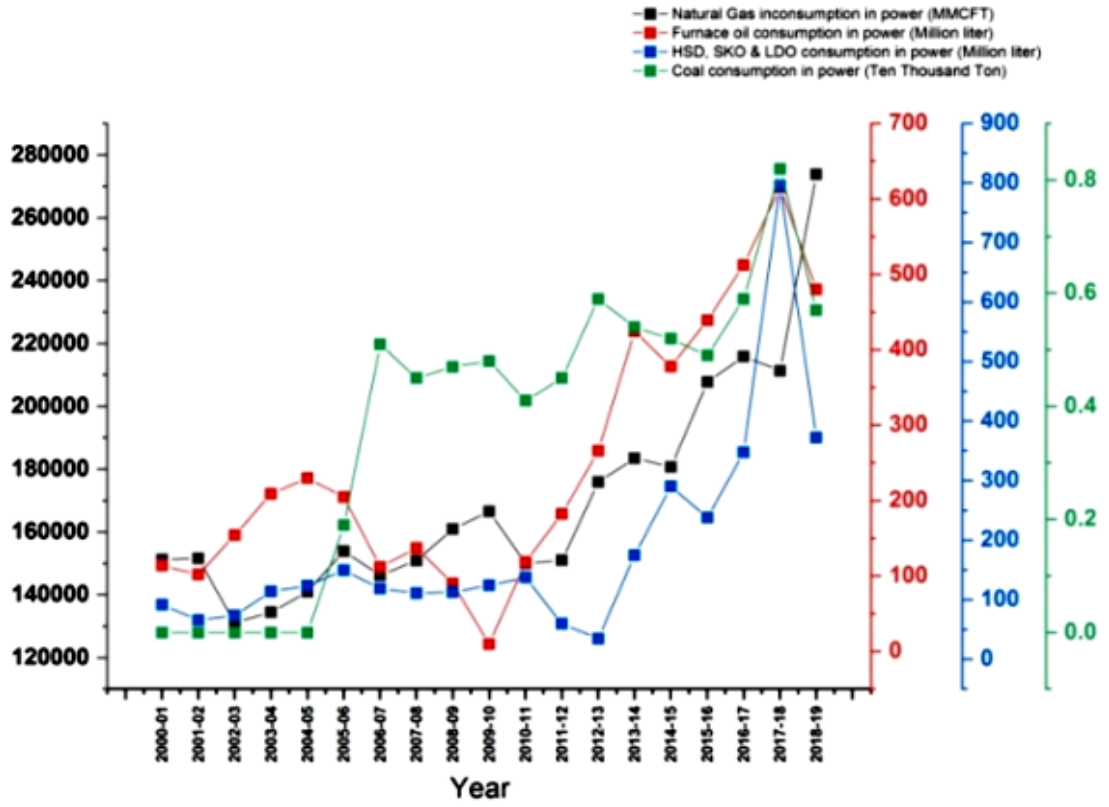

Fig. 18. Fuel consumption for energy generation [16].

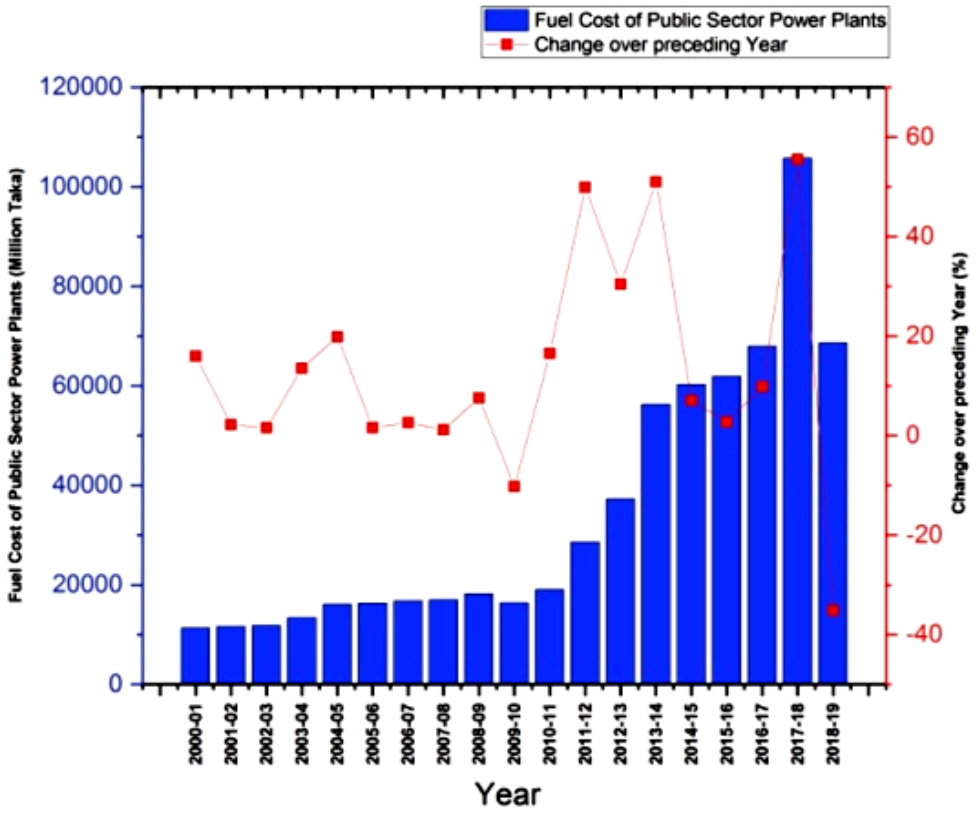

Fig. 19. Fuel cost of public sector power plants [16].

3.3 Progress in Renewable Energy Sectors

Solar and wind energy are the most useful renewable source of energy sources to generate electricity [18], [19]. From various reports of Bangladesh Government illustrate that country has the substantial potential of solar and wind energy. The country has almost 6250 square kilometres of available land where 156 GW of solar power can potentially be harvested through utility-scale solar farms (see Figure 20) [5].

Table 6 demonstrates solar energy potential in the country, which can be exploited to fulfil the energy demand to some extent.

Similarly, the country has at least 150 GW of wind power (on- and offshore) from sites that spread over 3200 square kilometres, mainly in the southern part of the country as shown in Table 7. This potential can be used to maximize local electricity generation [16].

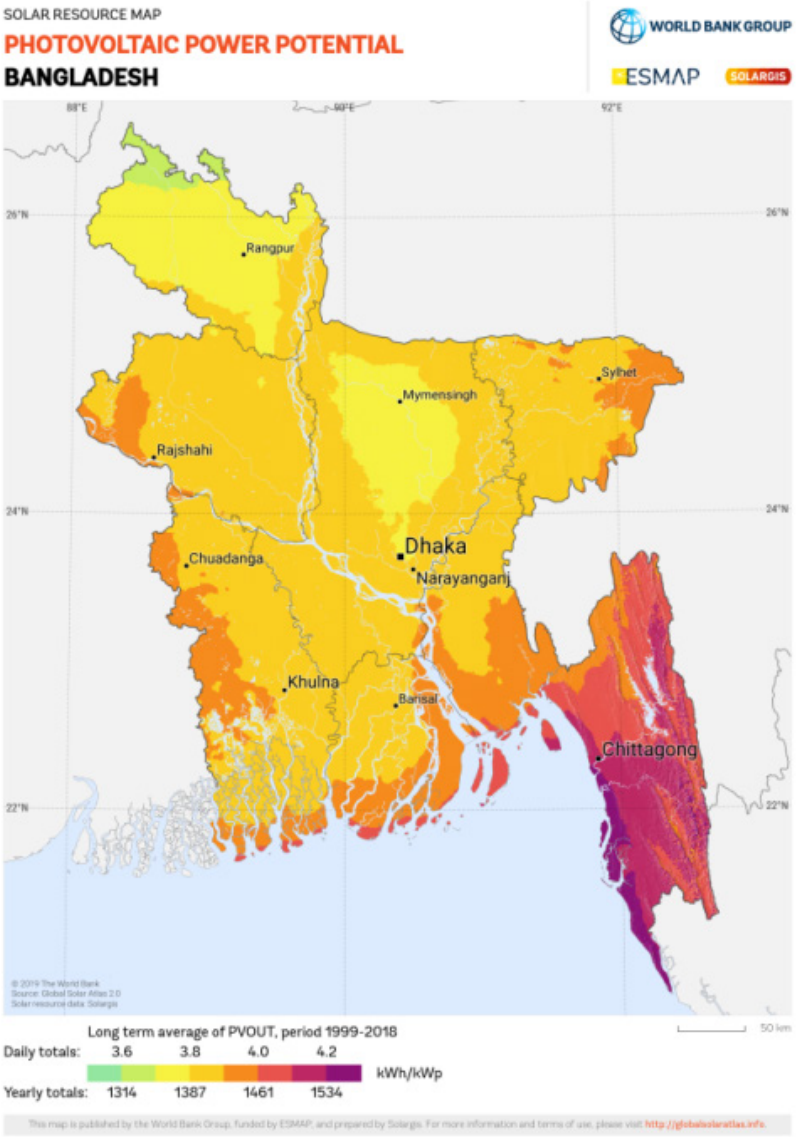

Fig. 20. The photovoltaic power potential of Bangladesh [5].

Table 6. Solar energy potential.

Resources	Maximum installable generation capacity (GW)	Maximum recoverable electricity (TWh/year)
Solar photovoltaic- rooftop	35	40
Solar photovoltaic- utility-scale	156	177
Solar photovoltaic- floating PV	31	35
Solar photovoltaic (total)	191	217

Source: ISF, January 2019, values are rounded.

Table 7. Wind energy potential.

Resources	Maximum installable generation capacity (GW)	Maximum recoverable electricity (TWh/year)
Wind- onshore	16	55
Wind- offshore	134	525
Wind total	150	580

Source: ISF, January 2019, values are rounded.

Currently, renewable energy share is less than 2% in the primary energy mix. Sustainable and Renewable Energy Development Authority (SREDA) stated that country has installed capacity of 633.36MW, in which solar, wind, hydro, biogas to electricity and bio-mass to electricity technologies are in use (see Figure 21). Solar energy contributes to the highest share of 63.08% with an installed capacity of 318.16 MW [20].

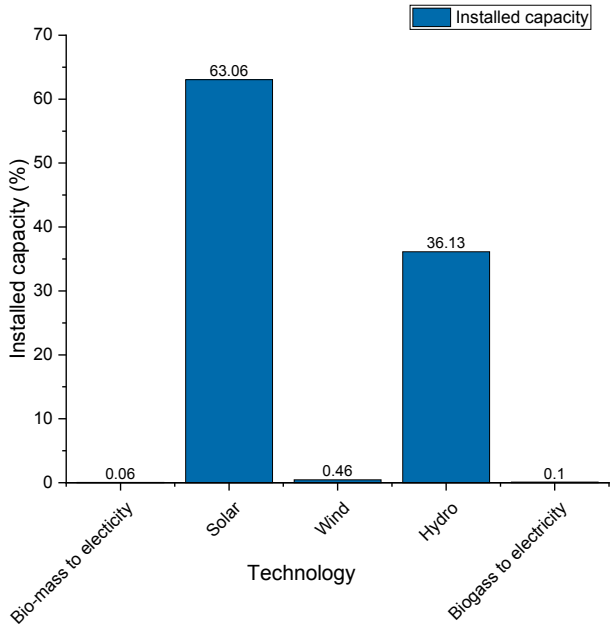

Fig. 21. Installed capacity of renewable technologies [20].

The country kept the goal of 10% energy generation using renewable energy by 2020. It has been forecasted that till 2025, solar photovoltaic and wind will overtake hydropower. The share of renewable power generation (PV, wind, and ocean) will increase from 12% to 23% by 2030 and 56% to 65% by 2050. Therefore, smart grids, demand-side management, energy storage capacities need to be expanded to increase the flexibility of the renewable power system for grid integration, load balancing, and a secure supply of electricity. Today, 51% of Bangladesh's energy demand for heating is coming from the use of traditional unsustainable biomass [14]. This load can be significantly reduced by promoting solar water heater, solar dryer [21]. Similarly, the technology of solar distillation systems [22], solar cooker[23], solar air heaters [24] must be promoted widespread, particularly in the remote and rural region. Solar distillation technology can be also useful even in small industrial applications [25].

4. PROGRESS OF BANGLADESH ON SDG-7 AS COMPARED WITH OTHER SOUTH ASIAN COUNTRIES

The principal boundaries of South Asia are the Indian Ocean, the Himalayas, and Afghanistan. This region is home to 2 billion populace living in eight different countries, namely Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka [26]. In this region, Bhutan and Sri Lanka are succeeded in providing 100% electricity access to all households; Bangladesh is also approaching to achieve this goal in recent years. Bangladesh produces power mostly from fossil fuel; hence contributes to GHG emission. Bangladesh stood on the third rank after India and Pakistan with GHG emission of 86.51 $MtCO_2$ as shown in Figure 22. Bangladesh can utilize its huge solar and wind energy potential to reduce its fossil fuel dependency, GHG emission, and can earn more carbon credits. In this way, the country can face the problem of climate change to some extent, i.e. attainment of SDG-13 [27].

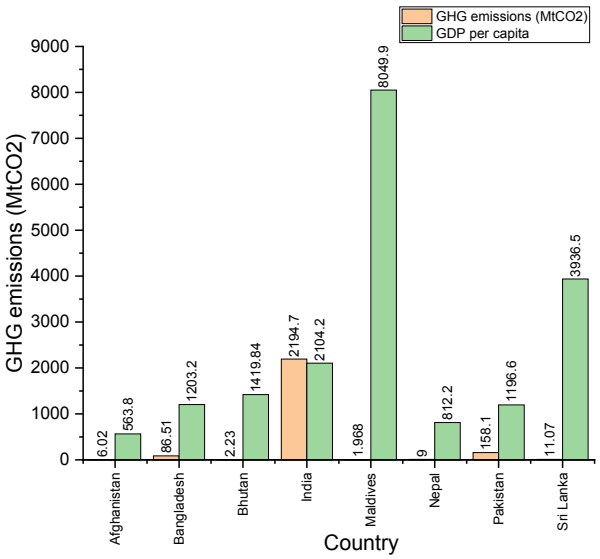

Fig. 22. GHG emissions (MtCO2).

From Figure 23, it can be recognized that among the South Asian countries, Bangladesh has lower per capita energy consumption (464 kWh per capita). It indicates that the people of Bangladesh have lower access to energy, particularly in the rural area; consequently, the economic growth of the country is comparatively slower as compared with other South Asian countries. This can be easily recognized by comparing the GDP of South Asian countries as shown in Figure 24.

Table 8 shows that the population of major Asian countries do not have access to the clean cooking energy source. Countries like India, Bangladesh, and Pakistan have more than 100 million people without access to clean cooking energy source [28].

Figure 25 shows the global economic rank and score of different South Asian countries. Bangladesh stood 11th out of 12. It means that people in Bangladesh are relatively underprivileged as compared with some other South Asian countries. The main reason behind this is the wide infrastructure gap as compared to other South Asian countries [29]. Multiple Indicator Cluster Survey (MICS) 2012-2013 conducted by UNICEF states that in Bangladesh, 88.2% of households use solid fuels, and 67.6% of household use of wood for cooking. Firewood is the most popular for cooking; almost 50.5% urban and 72% of rural households use firewood for cooking [20].

Bangladesh stands 8th out of 20 countries in the category of the number of people without access to electricity with 24 million people have no access to electricity, as shown in Figure 26.

Various reports published by the government of Bangladesh illustrate that there is a dependency on single fuel (natural gas) in the primary energy mix. Despite abundant renewable energy sources available across the country, the share of renewable energy in the primary energy mix is found very low as compared to other South Asian countries (see Figure 27) [30].

Table 8. Population without access to clean cooking energy [28].

Country	Number of people (Million)
India	853
Bangladesh	143
Pakistan	102
Afghanistan	26
Nepal	23
Sri Lanka	17

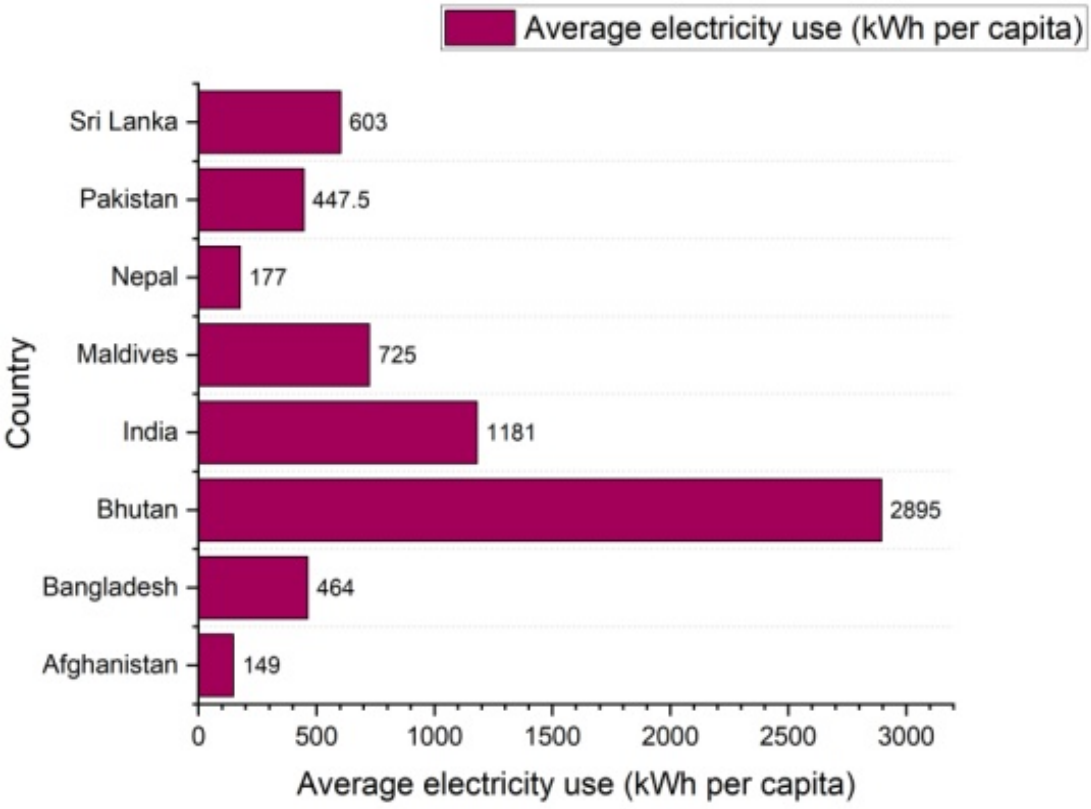

Fig. 23. Per capita energy consumptions of South Asian countries.

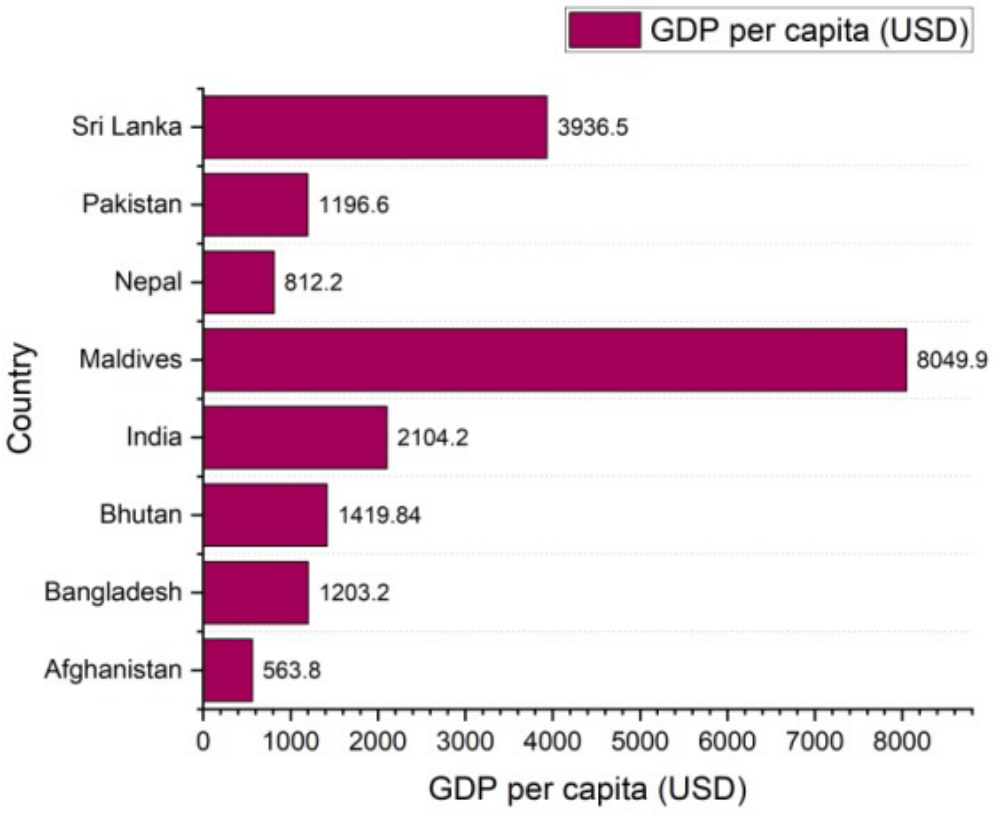

Fig. 24. GDP per capita of South Asian Countries.

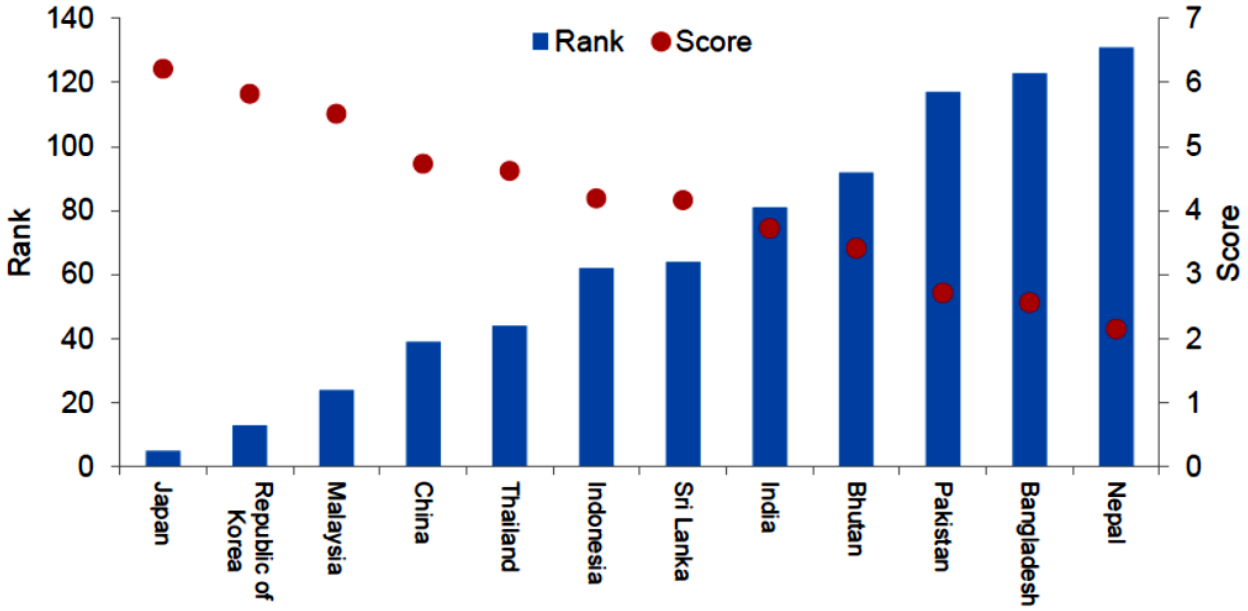

Fig. 25. Score and rankings of selected Asia-Pacific countries in the global [29].

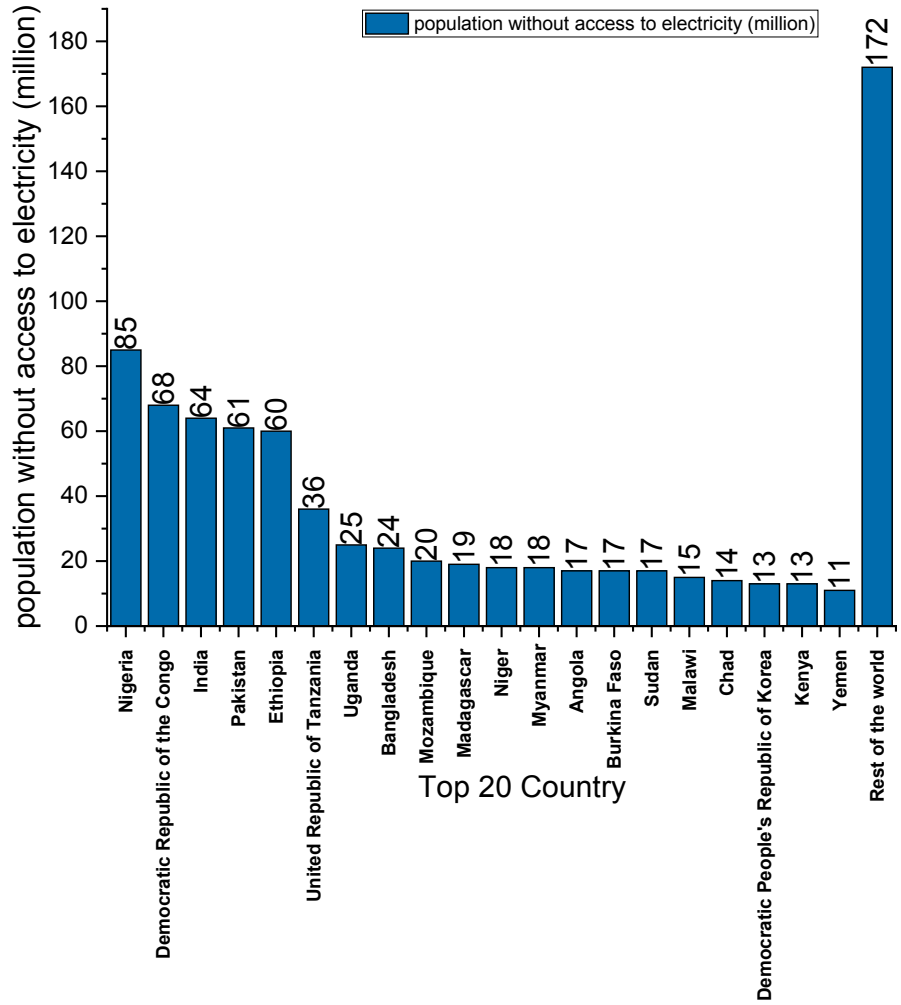

Fig. 26. Top 20 countries for people without access to electricity.

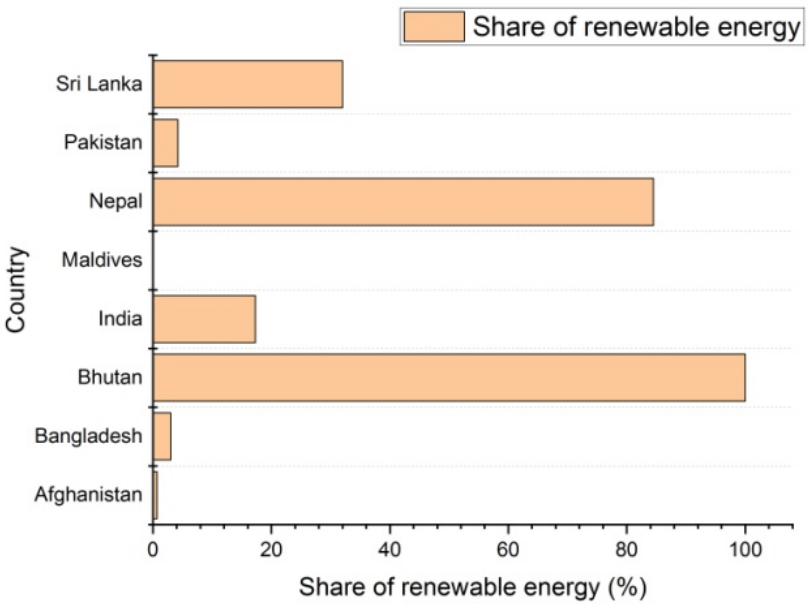

Fig. 27. Share of renewable sources in energy generation in percentage [16].

5. BARRIERS AND FUTURE CHALLENGES

There are many challenges in front of Bangladesh to attain SDG-7 such as [31,32]**:**

Policy level challenges

- Less priority is given to use renewable energy.
- Poor execution of renewable energy policies.
- Unnecessary fossil fuel financial subsidies.
- Lack of incentives for participation in renewable energy programs.

Technical challenges

- Insufficient local manufacturing units.
- Limited technical capability to design, install, operate, and maintain renewable energy services.
- Lack of standardized technology.

Economic challenges

- High installation and capital cost of renewable energy equipment.
- Long payback periods.
- Insufficient knowledge of market potential.
- Insufficient financial support from the government.

Information challenges

- Partial facility for renewable energy data collection, analysis, and project development
- Insufficient knowledge associated with renewable energy technologies, equipment suppliers, and financiers.
- Lack of information about renewable energy for policies.

5.1 Macro and Micro Initiatives to Attain SDG-7

The country is taking widespread efforts to attain SDG-7. Following are some outstanding initiatives:

5.1.1 Power balance constraints

World Bank Report-2018 states that 10700 people die annually due to indoor air pollution. To reduce indoor pollution, the Government of Bangladesh is promoting the use of efficient cookstoves. This program began in May 2013. Nearly 1.6 million clean stoves were installed in homes by January 2017. The government has launched the next phase of this program to install an additional 5 million stoves in the next five years and 30 million cookstoves by 2030 [33]. Due to the implementation of this program, GHG emission has been reduced by 2.890 MtCO2eq and firewood consumption has been reduced by 58%. Cookstoves have saved over 375.84 takas per stove per month with an annual saving of over 600 takas. This program reduces the time taken by each user to collect firewood by 102 hours per year. Government has kept the mission to reach 25 million people by 2030 [34]. In addition to this government can also develop waste oil cooking stove for small scale industries [35].

5.1.2 Electricity by Bio-mass Gastification

The country is moving forward to generate electricity by Bio-Mass Gasification and also planned to develop a coalfield of Phulbari, Dighipara, Khalashpir, and Jamalganj region for the future energy security [9]. The country has estimated total power generation from agriculture residue about 1178 MWe. From rice husk and bagasse estimated potential is 1010 MWe and 50 MWe respectively, and other resources can contribute 118 MWe. The share of forest and municipal waste could also be 250 MWe and 100 MWe respectively. National Database of Renewable Energy states that as on date one system is in operation named as SEAL biomass-based electricity project of 400 kW capacity at Thakurgaon [36].

5.1.3 Bio-gas

It is also noticed from various government reports of Bangladesh that, the country is not focusing on waste to energy conversion. Urban, semi-urban and rural, agriculture, and industrial waste can be used for energy generation indirectly in limited use to fulfil the demand of energy of particular community in rural and remote regions just like waste oil cooking stove for small hotels and restaurants [35]. Biogas plant for kitchen and rural waste to cater to the energy need of households is another attractive alternative [37]. First bio-gas plant in Bangladesh was set up in 1975. Now the government is operating scheme of the bio-gas plant through Slum Improvement Project (SIP). As of 2017, a total of 71396 biogas plants are in working, which saves around 8.52 tonnes of carbon dioxide emission annually.

5.1.4 Gramin-Shakti

Bangladesh government has started “Grameen Shakti” (GS) in 1996. It is a not for profit organisation working for the implementation of renewable energy programs in Bangladesh. It was started by the Grameen Bank’s (GB) managers to create a sustainable and profitable business. GS has developed a financial mechanism to promote solar home systems (SHS) in rural areas on a commercial basis. GS has a local Branch office which is very helpful to build rapport, creates awareness about SHS. GS also offers repair and maintenance services at free of cost to all its customers during the payment period. GS local office staff members are cross-trained to conduct sales, installations, after-sales service, and maintenance, as well as payment collections. The organizational structure of GS offers maximum operational flexibility to serve the people of the rural and remote regions. Till November 2017, GS installed 1 million solar-home systems [38].

5. CONCLUSION

This paper presents progress and challenges to attain SDG-7 by Bangladesh. From this study, the following conclusions are drawn:

- Bangladesh is facing the problem of energy scarcity to sustain economic growth.

- Most of the population of the country living in rural and remote regions do not have access to clean energy and electricity.
- Only 84.9% of the people of Bangladesh have access to electricity.
- Almost 143 million people in Bangladesh do not have the accessibility of clean cooking fuel sources.
- They use largely biomass for cooking and other domestic use.
- Bangladesh has taken many remarkable initiates at the macro and micro levels to attain SDG-7.
- Grameen Shakti is one of the best initiatives taken by Bangladesh.

Following are the few recommendations for effective implementation and attainment of SDG-7 for Bangladesh:

- Bangladesh must have diversification of fuel in primary energy consumption patterns. Presently, there is an enormous dominance of a single fuel (natural gas) in the energy.
- Bangladesh has a limited focus on renewable energy.
- Despite abundant renewable energy sources available across the region, they have not been efficiently tapped.
- With the huge availability of renewable energy potential, Bangladesh will not only solve the problem of energy scarcity but also save huge expenditure on imports of hydrocarbons.
- The governments of Bangladesh must promote the use of solar PV systems, solar cookers, solar distillation, and portable biogas plants for kitchen waste to cater to the energy need of households.

NOMENCLATURE

GB	Grameen Bank
GDP	Gross domestic product
GHG	Greenhouse gases
GS	Grameen Shakti
ISF	International Securities Finance survey
LNG	Liquefied natural gas
MICS	Multiple Indicator Cluster Survey
MMSCFD	Million standard cubic feet per day
PV	Photo-voltaic
SDGs	Sustainable development goals
SHS	Solar home system
SIP	Slum Improvement Project
SREDA	Sustainable and Renewable Energy Development Authority
TCF	Trillion Cubic Feet
UNICEF	United Nations International Children's Emergency Fund
WHO	World health organisation

REFERENCES

[1] Leach M. and S. Deshmukh, 2012. Sustainable energy law and policy. *Environmental and Energy Law* 122–38.

[2] Ambade S., Tikhe S., Sharma P., and Katekar V., 2017. Cram of novel designs of solar cooker. *International Journal of Mechanical Engineering Research* 7(2): 109–117.

[3] Deshmukh S., 2011. Energy resource allocation in energy planning. *Handbook of Renewable Energy Technology* 801–46.

[4] CIA World Face Book, 2004. Bangladesh. Retrieved from the World Wide Web: https://en.wikisource.org/wiki/CIA_World_Fact_Book,_2004/Bangladesh. CIA World Fact B 2004.

[5] Council CDPB for the WWF, 2019. *100% Renewable Energy for Bangladesh.*

[6] Hydrocarbon Unit of Energy and Mineral Resources Division, Ministry of Power, Energy and Mineral Resources, Bangladesh, 2019. *Energy Scenario Bangladesh, 2017-18.*

[7] Zimmer A., Hare B., and Beer M., 2019. Decarbonising South and South East Asia: Country profile Bangladesh. *Climate Analytics.*

[8] World Health Organization.. 2019. Country Profiles. Retrieved from the World Wide Web: https://www.who.int/apoc/countries/en/.

[9] Adnan M., Abir N., and Rahman T., 2018. Energy scenario of Bangladesh and future challenges. *International Journal of Scientific and Engineering Research* 9: 1001–1005.

[10] Nia A.B., Hermouet E., Shayani D., and Tran P., 2019. Asia and the Pacific SDG Progress Report. United Nations Publication.

[11] Khondaker D., Moazzem G., and Ali M., 2019. The power and energy sector of Bangladesh: Challenges of moving beyond the transition stage. *Centre for Policy Dialogue* 1–35.

[12] Deshmukh S., Jinturkar A., and Anwar K., 2014. Determinants of household fuel choice behavior in rural Maharashtra, India. 1st International. Congress on Environmental, Biotechnology, and Chemistry Engineering IPCBEE, IACSIT, Singapore.

[13] Mahmood K., 2019. Bangladesh Power Development Board. *Annual Report 2018-2019B Annual Report 2018-19*.

[14] Islam S. and M.Z.R. Khan, 2017. A review of energy sector of Bangladesh. *Energy Procedia* 110: 611–8. doi:10.1016/j.egypro.2017.03.193.

[15] Deshmukh M.K. and S.S. Deshmukh, 2006. System sizing for implementation of sustainable energy plan. *Energy Education Science and Technology* 18(1): 1-15.

[16] International Renewable Energy Agency (IRENA), 2020. The Energy Progress Report 2020.

[17] Leach M., Deshmukh S., and Ogunkunle D., 2014. Pathways to decarbonising urban systems. *Urban Retrofitting for Sustainability: Mapping the Transition to 2050.* 191–208. doi:10.4324/9781315850184.

[18] Anwar K. and S. Deshmukh, 2020. Parametric study for the prediction of wind energy potential

over the southern part of India using neural network and geographic information system approach. In *Proceedings of the Institution of Mechanical Engineers Part A Journal of Power Energy* 234: 96–109. doi:10.1177/0957650919848960.

[19] Anwar K. and S. Deshmukh, 2018. Assessment and mapping of solar energy potential using artificial neural network and GIS technology in the southern part of India. *International Journal of Renewable Energy Research* 8: 974–85.

[20] Toufique K.A., Narayan D., Paul R., Agargaon E., and Nagar S., 2018. *Fuel wood consumption in four districts of Bangladesh.* Bangladesh Institute of Development Studies.

[21] Katekar V., Vithalkar A., and Kale B., 2009. Enhancement of convective heat transfer coefficient in solar air heater of roughened absorber plate. In *Proceedings of the 2nd International Conference on Emerging Trends in Engineering and Technology (ICETET)* 1042–6. doi:10.1109/ICETET.2009.90.

[22] Katekar V.P. and S.S. Deshmukh, 2020. A review on research trends in solar still designs for domestic and industrial applications. *Journal of Cleaner Production* 257: 120544. doi:10.1016/j.jclepro.2020.120544.

[23] Ukey A. and V. Katekar, 2019. An experimental investigation of thermal performance of an octagonal box type solar cooker. Smart Technologies for Energy, Environment and Sustainable Development. *Lecture Notes on Multidisciplinary Industrial Engineering.* Singapore. doi:10.1007/978-981-13-6148-7.

[24] Durusoju M., Goyal C., Sheikh I., Dongre A., Marbate L., Rohit K., et al., 2016. An experimental investigation of thermal performance of solar air heater with 'W' wire mesh. *International Journal for Research in Applied Science and Engineering Technology (IJRASET)* 21-27.

[25] Mate A., Katekar V., and Bhatkulkar H.S., 2017. Performance investigation of solar still for batteries of railway engine: Indian Railways at Ajni Loco Shed, Nagpur. In *Proceedings of the International Conference on Advances in Thermal Systems, Materials and Design Engineering, VJTI*, Mumbai.

[26] Jinturkar A., Deshmukh S., Sarode A., Sunapwar V., and Khodke P., 2014. Fuzzy-AHP approach to improve effectiveness of supply chain. Supply Chain Management Under Fuzziness. *Studies in Fuzziness and Soft Computing* 313: 35–59.

[27] Cheng V., Deshmukh S., Hargreaves A., Steemers K., and Leach M., 2011. A study of urban form and the integration of energy supply technologies. In *Proceedings of the World Renewable. Energy Congress.* Linköping, Sweden. 57: 3356–3363. doi:10.3384/ecp110573356.

[28] Akhtar S., Hahm H., and Malik H.A., 2019. *Economic and social survey of Asia and the Pacific 2018.*

[29] Kumar N., Hammill M., Raihan S., and Panda S., 2016. Strategies for achieving the Sustainable Development Goals (SDGs) in South Asia: Lessons from Policy Simulations. *South and South-West Asia Development Papers 1601*, p. 33.

[30] Kharbanda V.K. and R.R. Panda, 2016. Report on Regional Energy/Electricity. *Regulatory Institutional Mechanism in South Asia: South Asia Forum of Electricity/Energy Regulators (SAFER)*. Integrated Research and Action for Development (IRADe).

[31] Lo K., 2017. Asian energy challenges in the Asian century. *Journal of Asian Energy Studies* 1: 1–6. doi:10.24112/jaes.010101.

[32] Koyama K., 2016. Challenges for Asian energy markets as a gravity center of the world. *IEEJ Energy Journal* 3–6.

[33] Power Division, Ministry of Power, Energy and Mineral Resources. Government of the People's Republic of Bangladesh, 2012. *Country Action Plan For Clean Cookstoves.*

[34] Ahmed F., Al Amin A.Q., Hasanuzzaman M., and Saidur R., 2013. Alternative energy resources in Bangladesh and future prospect. *Renewable and Sustainable Energy Reviews* 25: 698–707. doi:10.1016/j.rser.2013.05.008.

[35] Jambhulkar G., Nitnaware V., Pal M., Fuke N., Khandelwal P., Sonule P., et al., 2015. Performance evaluation of cooking stove working on spent cooking oil. *International Journal of Emerging Science and Engineering.*

[36] Farabi-Asl H., 2019. *Energy challenges for clean cooking in Asia, the background, and possible policy solutions.* ADBI Working Paper Series.

[37] Bhujade S., Mate A., Katekar V., and Sajjanwar S. 2017. Biogas plant by using kitchen waste. *International Journal of Civil, Mechanical and Energy Science 64–9.* doi:10.24001/ijcmes.icsesd2017.74.

[38] Modak G.C., 2019. *Grameen Shakti Annual Report.*