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Low-Carbon Energy Technologies: Potentials of Solar and Nuclear Energy Sources for Sustainable Economic Development in Bangladesh

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Abstract

Electricity shortage has become a major challenge to continued economic growth in Bangladesh. The country is growing in terms of GDP growth at a rate of 7% a year. Bangladesh is expected to move towards 23rd position globally by 2050 from its position 31 in 2014, in terms of GDP at purchasing power parity (PPP). The demand for electricity is forecasted to be 61,164 MW within the same period. Currently, electricity generation in Bangladesh is highly dependent on fossil fuels, nearly 59% is produced from natural gas followed by furnace oil, diesel and coal, while only 3% from renewables. Electricity generation is the largest single source of GHG (greenhouse gas) emissions in Bangladesh, and thus finding alternative energy source has become imperative for the country. Solar and nuclear energy sources have the potentials to be utilized for low-carbon energy sector and thus for a sustainable economic development in Bangladesh. Barriers to solar and nuclear energy will be reduced significantly in coming years with technological advancement. However, energy policies need to be revised to facilitate low-carbon energy technologies. Besides, more international collaboration is highly required not only to import new technologies but also to enhance the capacity of research and development (R&D) as well as overall adoption of the technologies.

Keywords: Economic Growth, Electricity Shortage, Fossil Fuel, Greenhouse Gas, Low-carbon Energy, Renewable Energy, Nuclear Energy, Bangladesh

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1. Introduction

Electricity is one of the main driving forces for any economy and often per capita electricity consumption is an important development indicator of a country. It is obvious that the demand for electricity will continue to increase with economic growth such as increase in gross domestic product (GDP) or per capita income. The gap between demand and supply of electricity will increase with economic development if increase in electricity generation is not planned proactively.

The population of Bangladesh is expected to increase to 202 million by 2050 from 166 million in 2018 (Populationpyramid, 2018). Concurrently, Bangladesh is also growing in terms of GDP at a rate of 7% a year. To sustain the current economic growth, increased attention needs to be paid to provide energy supply, especially electricity supply. Hawksworth and Chan (2015) showed in their report "The world in 2050: Will the shift in global economic power continue?" that Bangladesh will move towards 23rd position by 2050 from its position 31 in 2014, in terms of GDP at purchasing power parity (PPP), followed by Malaysia, Spain, Argentina, Netherlands. From this projection, future electricity demand will rise significantly due to increased economic activities including urbanization, and expansion of manufacturing and service sectors. Thus, we should diversify our electricity generation technologies using renewables and nuclear energy resources to meet the excess demand. One of the major advantages of these resources is that they emit significantly low greenhouse gases (GHGs) compared to currently used fossil fuels in the generation of electricity. Although coal represents the largest share in electricity generation globally followed by natural gas, hydro and nuclear energy, it is expected that low-carbon energy technologies will dominate the sector (Beckjord et. al., 2003).

1.1 Current electricity generation practices in Bangladesh

Electricity consumption in Bangladesh is rising by 9.6% each year (UNIDO, 2016). Currently, fossil fuels are playing the vital role in the generation of electricity in Bangladesh. Natural Gas is the largest source of the country's commercial electricity generation (nearly 59%) followed by furnace oil, diesel and coal (Fig. 1). It is evident that the country's reserve of gas will be depleting fast if no new gas field is discovered. The present reserve is not sufficient to meet our upcoming demand. This means, we will have to import natural gas from abroad. Impact of importing natural gas will incur additional pressure on foreign currency reserve and increasing consumption of natural gas will significantly increase the emissions of GHGs. Thus, we need to reduce dependency on this fossil fuel, introducing alternative energy sources like renewables and nuclear energy in the generation of electricity. Bangladesh has no significant oil reserve and depends on imported crude and refined petroleum products for transportation, industrial heating and small-scale power generation. A large amount of revenue budget is spent every year for purchasing imported petroleum products.

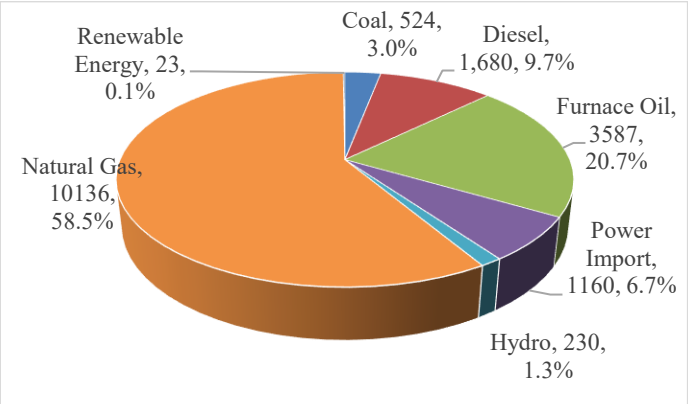

Figure 1. Fuel mix in the production of electricity in Bangladesh. Total electricity installed capacity (17,340 MW) by fuel type on Oct, 2018 (BPDB, 2018)

Coal energy is the most abundant and economical energy sources not only in Bangladesh but also all over the world. Currently, coal accounts for 39.8% of the world's electricity generation. In Bangladesh, coal represents 3.25% of the actual generated electricity. Coal reserve is estimated to be 3300 million metric ton which is equivalent to 45–50 trillion cubic feet (CFT) of natural gas (Islam et. al., 2014). However, extensive use of coal in electricity generation will significantly increase GHG emissions.

Non-renewable fossil fuels cannot be the ultimate solution for sustainable power sector due to their various adverse impacts on our environment. We need to move towards cleaner electricity generation technologies using renewables such as wind, solar, hydro, geothermal etc. or low-carbon energy resources such as nuclear fuels. Currently, renewable energy sources have a very low share of the total electricity generation in Bangladesh, which is less than 3% (Islam and Khan, 2017). The government of Bangladesh has developed renewable energy policy in 2008 and has taken a number of initiatives to increase the use of renewable and also encouraging public private partnership to increase investment in renewable electricity generation (MPEMR, 2008).

The 230 MW hydropower plant located at Karnafuli currently provides the major share of total renewable energy in Bangladesh. Bangladesh Power Development Board (BPDB) identified two other sites at Sangu (140 MW) and Matamuhuri (75 MW) for large hydropower plants (UNIDO, 2016), however the potentials for large-scale hydropower plant installation in Bangladesh is limited.

Wind Energy has also a limited potential in Bangladesh. The long-term wind flow of Bangladesh (specifically in islands and the southern coastal belt of the country) indicate that the average wind speed remains between 3 to 4.5 m/s for the months of March to September and 1.7 to 2.3 m/s for remaining period of the year. There is an opportunity to use wind energy in island and coastal areas for the application of wind mills to generate electricity. But during the summer and monsoon seasons, (March to October) there can be very low-pressure areas and storm with wind speeds of 200 to 300 km/h. Therefore, wind turbines should be strong enough to withstand these high wind speeds, which will increase the initial cost of wind turbine installation (MPEMR, 2004).

2. Prospects of solar and nuclear energy technologies

Solar energy is one of most promising renewable energy sources in the world. It has the highest potential to gain energy compared to other renewables. Solar energy is expected to account for 35% of power-generating capacity additions worldwide, triggering investments in the order of $3.7 trillion between 2015 and 2040 (Nava, 2015). The long-term average sunshine data of Bangladesh indicates that the period of bright (i.e. more than 2 kWh/m2/day intensity) sunshine hour in the coastal region varies from 3 to 11 hours daily. The global radiation varies from 3.8 kWh/m2/day to 6.4 kWh/m2/day. These data indicate that there is a good prospect for solar thermal and photovoltaic application in Bangladesh (MPEMR, 2004). Although solar energy harvesting at commercial scale is a fast-growing technology around the world, this technology possesses some challenges, which might be solved to take full advantage of solar power generation. Apart from low efficiency of solar energy, electricity produced from solar system varies during the day, thus challenges arise both technical and economic. At most sites, integration of small shares of solar power requires adaptation of the electricity grid. As the shares increase, the need for adaptation increases and the integration costs may rise.

Electricity production from renewables alone will not be sufficient to meet the increased electricity demand for Bangladesh in the future. Nuclear power could be a potential alternative solution for electricity generation. Nuclear power is an intense source of energy. It is the largest source of low-carbon electricity in the developed world and the second largest, after hydroelectricity (Hirst, 2018). The efficiency of nuclear power is well-documented. As for example, 1 kg U-235 can produce more than 24 million kWh of electricity (Karimet.al., 2018), while a combustive or fission-based process yields 8 kWh of heat via conversion from 1 kg coal and the same amount of mineral oil results in 12 kWh (Beckjord et.al., 2003). Besides, the transport infrastructure needed for nuclear fuel is also significantly small. 1,000 MWe (Mega Watt Electricity) nuclear power capacity needs only about 30–35 tons of enriched fuel per annum, as against 3.5–5.0 million tons of coal needed for a coal fired thermal power plant (Bhardwaj, 2013).

Bangladesh government has already started the construction of its first nuclear power plant (NPP) in 2017, with two units of 1200 MW each, at Rooppur, Pabna though an Inter-Governmental Agreement (IGA) with Russia (Rooppur NPP, 2017). Rooppur NPP is expected to be commissioned by 2023 with a life expectancy of 60 years. As nuclear power plant has nearly zero carbon emission, it will help building low carbon society.

Nuclear power presents numerous advantages; however, the main drawbacks of nuclear energy lies on i) safety and security issues in terms of technical knowhow, natural disasters and terror attacks, and ii) disposal and management of nuclear wastes. In this regard, we need to have solid plan to develop our own human resources and to adopt state of the art technologies in eliminating any risk associated with nuclear power and develop nuclear waste management process.

The development and deployment of nuclear reactors are influenced by many factors. Reviewing published reports and literature, this article perhaps identified six major factors namely: cost-effectiveness, safety, security and non-proliferation features, grid appropriateness, commercialization roadmap (including constructability and licensability), and management of the fuel cycle. Nuclear reactor designs are usually categorized by "generation"; that is, Generation I, II, III, III+, and IV. The key attributes characterizing the development and deployment of nuclear power reactors illuminate the essential differences between the various generations of reactors. Gen II reactors are the first commercially available reactors type. Gen III+ reactor designs are an evolutionary development of Gen III reactors, offering significant improvements in safety over Gen III reactor designs certified in the 1990s.

Gen IV nuclear reactor design uses a variety of methods to enhance safety, to minimize radioactive waste by recycling and using waste in the generation process, and to eliminate proliferation of weapons grade materials. The aim is to have a reactor, which produces very little radioactive waste with much longer lifespan and closed fuel cycle. It is expected that the Gen IV designs will be certified for commercial use by 2030, which will make disruptive change in nuclear power sector. Figure 3 shows evolution of different nuclear reactor types with their advantages in commercialization.

3. Electricity demand projection of Bangladesh

There is a direct correlation of the consumption of electricity with the GDP growth. It's already mentioned that Bangladesh's average GDP growth rate is projected to be 7%. According to the power system master plan (PSMP) 2010 (MPEMR, 2016), electricity demand is forecasted to 66,164 MW by 2050 based on 7% GDP growth rate. Considering de-carbonization of the electricity generation system, alternatives of fossil fuels such as renewables and nuclear energy will have to be utilized to fulfil the required demand of the nation. Although ensuring the supply of this forecasted demand is challenging, however continuing reforms, restructuring and a focus on energy conservation could led to achieve this challenging target. One of the major barriers to meet this optimistic target is the shortage of funds to be invested in the development of infrastructures. Necessary attention need to be given to formulate appropriate policies to encourage private sector participation in energy sector development program to meet the shortage of fund. More recently, public private partnership (PPP) has been fueled with top priority to attract private investment in energy sector (MPEMR, 2004; MPEMR, 2008).

4. Electricity cost using different technologies

Nuclear power plants are expensive to build, but relatively cheap to run. In many places, nuclear energy is competitive with fossil fuels as a means of electricity generation. The levelized cost of electricity (LCOE) is a measure to compare different technologies of electricity generation on a comparable basis. At 3% discount rate, nuclear was substantially cheaper than the alternatives, at 7% it was comparable with coal and still cheaper than gas, and at 10% it was comparable with both (Fig. 2) (Beckjord et.al., 2003).

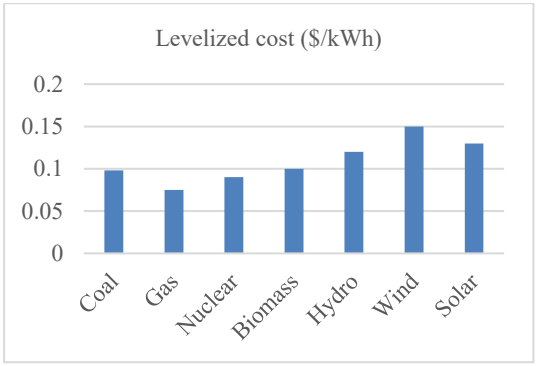

Figure 2. Levelized energy costs for new power plants

Besides, fossil fuel-based electricity production will be further unattractive due to their extremely high carbon emission and price volatility of the primary energy resources. Nuclear power is environmentally benign and the life cycle GHG emissions of nuclear power are comparable to that of wind and solar photovoltaic power. The life cycle emissions (from mining of ore to waste disposal) of nuclear power are very low, between 2.5 and 5.7 gCO_2eq/kWh as against 206 to 357 gCO_2eq/kWh in case for coal and 106 to 188 gCO_2eq/kWh for gas technologies (WNA, 2011).

Unit production cost of solar electricity is high compared to fossil fuel generated electricity, however, if carbon taxes and costs over the lifespan of energy projects are considered, both solar and nuclear energy technologies can be much less expensive. Table 1 presents comparative cost and emission assessment of different energy technologies.

Table 1. Comparison of different energy technologies (Beckjord et.al., 2003; OECD-NEA, 2015; UCS, 2017)

Parameter	Solar	Wind	Nuclear	Gas	Coal
Capital cost ($/kW)	2,000	1,200-1,700	4,100	1,000	2,125
Electricity cost ($/MWh)	43-53	30-60	29-82	42-78	>60
CO_2 emission (Kgequivalent/MWh	30-90	6-124	2-130	270-910	640-1630
O&M cost ($/MWh)	5.71-80.97	8.63-53.97	7.04-29.79	1.32-7.83	1.51-37.89

5. Future energy policy of Bangladesh

Future energy policy should focus more on carbon free energy technologies due to global & local concern regarding climate change. Among all the clean energy technologies, only renewable and nuclear technologies could be effectively utilized as the potential clean/low-carbon sources of electricity generations. The major highlights of the future energy policy, especially policy related to electricity generation, should have the following specific objectives:

i) Reduce dependency on fossil fuels
ii) Ensure lowest unit cost of electricity production, especially using solar & nuclear energy sources
iii) Secure clean and efficient energy technologies
iv) Propose the forms of restructuring and reform of the energy sector enhancing the capacity of manpower and reduced dependency on other countries or external manpower
v) Create a comprehensive legal and regulatory system
vi) Conduct effective profile-raising activities to generate greater awareness and acceptance

5.1 Future of solar energy in Bangladesh and development

Bangladesh is blessed to have a huge amount of solar energy due to its geographical location, however the technology is yet to be utilized for commercial scale power production with high potential. Major drawbacks include i) high initial investment, ii) long payback period, iii) availability of sufficient land for infrastructure construction and iv) inadequate purchase policy. Policy supports from the government could intensify the installation of commercial solar power station.

5.2 Suggested reform and restructuring of solar energy applications in Bangladesh

Global renewable energy markets are driven by legal compulsory means to promote renewable energy development, namely a) compulsory quota policy, b) compulsory purchase policy and c) voluntary purchase policy. In terms of renewable energy development speed, the compulsory purchase policy is the most effective measure. The policy will have a mandate that electricity users, including grid companies, electricity retail companies, and large end-users participating in direct power purchasing a percentage quota of their electricity that needs to come from renewable energy.

Another common global practice is to provide economic incentives to promote solar electricity generation. In this regard, following policies could be adopted:

i) Subsidize investors, producers and users of renewable energy resources for a certain period.
ii) Impose environmental protection tariff on non-solar resource users or producers and introduce levies on pollutant emissions.
iii) Reduce or remove tax burden for public and private investors on solar energy applications
iv) Increase the amount of funding for R&D in solar energy and develop technical guidelines and codes on solar energy applications
v) Bring privates companies and Investors in the consortiums for solar energy supply and building infrastructure in the country
vi) More International collaboration projects to enhance the capacity of R&D as well as total production.

5.3 Future of nuclear energy in Bangladesh

Nuclear energy has to overcome the inefficiencies in the energy mix, security of energy supply, climate change, its cleanness as less carbon polluting than fossil fuels, raw material availability, technicians and scientists' interests, etc. (Hibbs, 2018). In 2016, 13 countries generated more than 30% of their total electricity from nuclear: France generated 77.7% of its electricity from nuclear power; Slovakia, 54%; Belgium, 54%; Ukraine, 47.2%; Hungary, 43.3%; Slovenia, 41.7%; Switzerland, 40.9%; Sweden, 39.6%; South Korea, 34.6%; Armenia, 33.2%; Czech Republic, 33.0%; Bulgaria, 32.6%; and Finland, 31.6% (Hawksworth and Chan, 2015; Beckjord et. al. 2003). These figures clearly suggest that a large fraction of nuclear power production is feasible for Bangladesh as well.

5.4 Suggested reform and restructuring of nuclear energy applications in Bangladesh

The Government of Bangladesh has taken initiatives for necessary changes in establishing regulatory issues before starting their very first NPP project. Although the initiatives are good start, there remain certain regulatory concerns which must be developed and or revised for a safe and sustainable nuclear power sector. We have assessed global nuclear energy industry to outline reform and restructuring of Bangladesh's nuclear energy sector. Following issues must be implemented in different stages for a sustainable nuclear energy sector.

i) Updating current nuclear energy policies and strategies including commissioning and decommissioning of NPP, radiation protection, nuclear waste management, and interim storage planning of nuclear waste
ii) Policy guidelines for small nuclear power plant (SPP) and nuclear power purchase from captive power plant

iii) Public and private partnership (PPP) nuclear power generation policy to bring privates companies and Investors in the consortiums
iv) More International collaboration with the supports from IAEA to enhance the capacity of R&D as well as total production.

6. Conclusions

As a country of severe electricity crisis, Bangladesh is looking forward to alternative sources such as renewables and nuclear energy in addition to fossil fuels for reliable and secured electricity supply for sustainable development. With current development growth, electricity demand will be five times higher by 2050 than current consumption level. Energy supply will have to be ensured to secure desired socio-economic development growth. Bangladesh has taken several initiatives to increase the generation of electricity in recent years reducing the dependency in fossil fuels and increasing the share of low-carbon technologies including nuclear and solar energy sources. This article has highlighted to strengthen the capacity of solar and nuclear energy for sustainable energy sector in Bangladesh.

Solar energy has a great potential to be expanded in Bangladesh due to very high availability of sunshine throughout the year although this technology is being limited due to the constraint of land availability, low efficiency and high capital costs. Nuclear power on the other hand has security concerns and very high capital investment as well as longer construction period. Besides, radioactive waste management is also a vital and critical issue. However, these drawbacks will be reduced significantly in the coming years with technological development.

This article pinpoints the current and future energy scenario and highlighted required actions programs, development of legal, regulatory, professional bodies to ensure expected development of solar and nuclear power sector. With the implementation of those actions/programs, including formulation and restructuring of energy policies to facilitate low-carbon energy technologies, Bangladesh can ensure sustainable power sector, meeting future demand of electricity, which might help the sustainable economic development of the country, transforming us to a developed nation by 2041. More international collaboration in this regard is highly required not only to import new technologies but also to enhance the capacity of research and development (R&D) as well as overall adoption of the technologies.

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