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Policy Paper on the Post Covid-19 Sustainable Energy Options for Power Generation in Bangladesh

Sakib Bin Amin*, [1], Adib Ahmed[+], Abdul Mahidud Khan[+] and Farhan Khan*

Abstract – *The central role of electricity in shaping the worldwide economy is broadly acknowledged in the energy literature. Having identified the then ongoing crisis of the electricity sector, the present Awami League government initiated restructuring the energy sector since 2009 to quicken the pace of the developmental activities. All these efforts resulted in landmark achievements in the Bangladesh energy sector, especially in increasing the electricity generation capacity. However, the global Covid-19 pandemic and its aftermath effects on the Bangladesh economy require a policy revision in Bangladesh's energy sector and electricity generation mix. To our knowledge, there is no study to analyse the adverse consequences of the Covid-19 in Bangladesh energy sector. By employing a SARIMA forecasting model, we reveal that electricity demand will remain less than the actual generation in the upcoming two years. Also, the DGE model finds that due to Covid-19, the economic growth rate will be around 4.5 percent in the long-run. We further simulate that the steady-state electricity demand and standard consumption values would fall by 8-10 percent and 6 percent, respectively. We recommend that a review of the power sector master plan is needed for future energy security and economic stability in Bangladesh.*

Keywords – *Bangladesh, Covid-19, dynamic general equilibrium model, SARIMA model, sustainable energy options.*

1. INTRODUCTION

The novel Coronavirus Disease 2019 (Covid-19), which emerged at Wuhan, China, in December 2019, has spread worldwide in a quick time and declared a pandemic by World Health Organization (WHO) on March 11, 2020. Though the outbreak of this pandemic has been diminished in China as a local shock [1], the number of Covid-19 affected people and the death toll keeps increasing worldwide as a global shock. As of August 2020, around 25.27 million infected cases were confirmed, and 0.87 million deaths were reported around the world (Figure (1(a)) [2].

In Bangladesh, the first Covid-19 report was confirmed for March 8, 2020. Since then, the number of affected people has been increasing rapidly. Bangladesh has reported 0.3 million infection cases and 4,281 deaths until August 2020 (Figure1 (b)) [2]. Although it may be evident that the severity of Covid-19 has slowed down recently as the global lockdown is withdrawn globally, Strzelecki has found evidence of a worldwide second wave of coronavirus from the outbreaks in South Korea, Italy, and Iran [3].

The covid-19 pandemic has constrained economic mobility, caused the shutting down of the factories, and stopped the education and training of people around the world [4]. Besides, restrictions on international travel and tourism, and many other sectors are also severely affected by the outbreak [5].

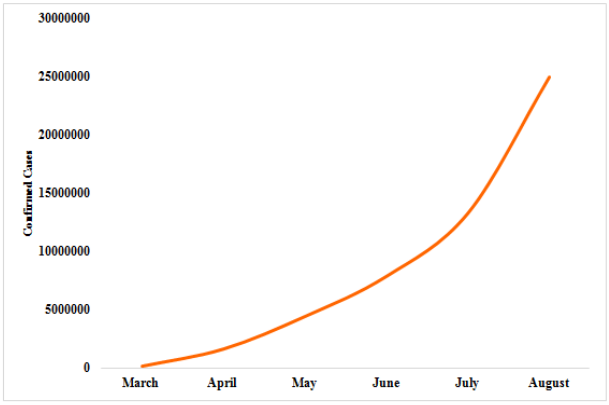

Fig. 1(a). Worldwide total confirmed Covid-19 cases (until August 2020). *(Source: Worldometers Report, 2020)*

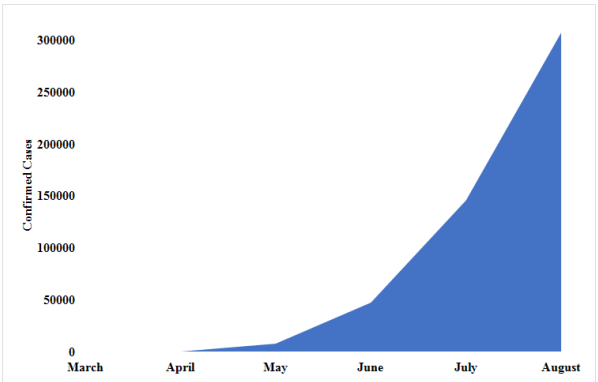

Fig. 1(b): Bangladesh's total confirmed Covid-19 cases (until August 2020). (Source: Worldometers Report, 2020)

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The pandemic also significantly affects the energy sector, with a nosedive in total energy demand, driven by a fall in business and industrial activities [6]. Due to this lockdown, transportation usage has been dropped substantially, resulting in a reduction in global fossil fuel consumption, leading to a fall in environmental pollution [7]. The aviation industry worldwide is also affected adversely, causing a massive decline in global oil demand.

Although it is argued that the Covid-19 may hurt the energy sector, very few studies have been conducted on the impacts of the Covid-19 outbreak on the energy sector. Eroğlu has conducted a literature review on the effects of the Covid-19 outbreak on the renewable energy sector and the environment from a global perspective [8]. He also has discussed the importance and scopes for future research of this topic in achieving future global energy security.

Akrofi and Antwi have reviewed the challenges posed to Africa's governments' energy industry [9]. They have found that most of the government initiatives are short-term focused (fiscal or financial measures). They have also revealed no specific mention of standards for the energy sector, especially for the renewable energy sector from medium to long-term. The study has recommended that the government should tackle the pandemic's aftershock challenges in the energy sector and drive the clean energy transition and bolster their economies.

In his study, Hosseini has further highlighted that the pandemic caused a short-run shrinkage towards globally developing sustainable renewable energy. The governments should offer incentive packages to stimulate the private sectors and society to invest in renewables [10]. Gillingham *et al.* revealed that the lockdown and the reduced volume of economic activities had improved air quality in the USA [11]. However, they argued this improvement as a temporary phenomenon as the investment in the clean energy projects is expected to decline as a move towards diverting the resources in the other prioritising sectors like health, education, etc.

Mastropietro *et al.* have emphasised the direct impact of the Covid-19 pandemic on the energy sector [12]. They have discussed that this global lockdown situation could deteriorate the energy insecurity around the world. The study has also identified some of the governments worldwide' emergency initiatives and recommended to provide assistance based on appropriate targeting and steady financing to reduce inefficiency.

The Covid-19 global pandemic has recently evolved into an economic and a humanitarian crisis of mammoth proportions. As governments have put restrictions on the movement of the populations to contain the epidemic to save lives, regular economic activities have been disrupted, leaving millions of people jobless, and pushing them into poverty and hunger. The pandemic has already slowed down Bangladesh's economic activities, and the most widespread impact of this slowdown has been a loss of income for most 52 million informal workers [13], [14].

The aftermath of the pandemic urges the revision of the existing energy policy in Bangladesh for twofold reasons: poor performance in improving the off-grid electrification by expediting renewable energy and the issue of recent generation overcapacity. So far, only 633.31 Megawatt (MW) of electricity (2.85 percent of the total generation capacity) is produced from renewables, which is far less than the actual target of generating 10 percent of renewable electricity energies.

The concern of generation overcapacity, underutilisation of the power plants, and the fiscal burden has been exacerbated during the Covid-19 period and further expected to deteriorate in the post-pandemic era in Bangladesh [15]. For instance, the overcapacity rate of 49.8 percent in 2020 is found well above the targeted reserve capacity of 25 percent, as mentioned in the Power Sector Master Plan (PSMP) 2016 [16].

Given this background, we argue that there is a necessity to study the post-pandemic consequences on the Bangladesh energy sector to revise the existing power sector master plan and help the country achieve the Sustainable Development Goals (SDGs) and ensure energy security, and become a high-income nation by 2041. Bangladesh Power Development Board (BPDB) also suggests that this is the optimal time to change the power generation policies for long term energy security and economic sustainability.

To our knowledge, there is no previous study to analyse the adverse consequences of the Covid-19 in Bangladesh energy sector and the other similar countries. This paper's main objective is to examine the short-run and long-run effects of the Covid-19 pandemic on the Bangladesh energy sector and economy for future policy revision in the energy policies in terms of the generation mixes.

We use a Seasonal Autoregressive Moving Average (SARIMA) model to generate a counterfactual demand in the nationwide general holiday period using the SARIMA (1, 0, 0) (0, 1, 0) [12] model. Also, we forecast the electricity demand for Bangladesh for the next two years, using electricity data until June 2020, and find SARIMA (1,0,0) (1,1,0) as the best-suited model for this period of data. Moreover, to capture the long-run effects of the Covid-19 aftermath in the energy sector, we employ a Dynamic General Equilibrium (DGE) model developed by Amin and Marsiliani [17] Bangladesh energy sector. The assumptions made and the functional forms of the model follow those of Kim and Loungani(1991) and Dhawan and Jeske (2008) [18], [19].

The benchmark model is calibrated and simulated for the Bangladesh economy, with a no lockdown scenario (government does not impose a general holiday). In the policy experiment, we simulate an economy where the government imposes general holiday, reducing the labour availability by 50 percent

and finding results in terms of the steady-state values of the GDP, standard consumption, and electricity consumption.

The paper is organised as follows. Recent power generation options in Bangladesh are presented in Section 2, followed by a discussion on the economic impact of Covid-19 in Bangladesh in Section 3. Section 4 briefly discusses the SARIMA and DGE models and discusses the effects of Covid-19 in the Bangladesh energy sector. Finally, conclusions and policy implications are presented in Section 5.

2. RECENT POWER GENERATION OPTIONS IN BANGLADESH

When the present government came into power in 2009, they faced two major problems in the energy sector. Firstly, the economy was not reaching its full potential due to an inadequate supply of electricity. During 2000-2009, electricity demand always exceeded supply by 2,000 MW on average. Secondly, the country faced too much reliance on natural gas as more than 90 percent of the electricity was produced using natural gas up to 2009. However, the reserve of natural gas in Bangladesh is limited and expected to last until 2031 [20], [21]. Moreover, Bangladesh's energy security and economic stability were threatened by the scarcity of fossil fuel resources, poor operational maintenance, financial performance, lack of trained human resources, and a low number of electricity generation plants. Realising the energy sector's decisive role in the country's development process, the present government started a wide range of reform policies since 2009 [22].

Bangladesh's government started undertaking the reform initiatives to ensure necessary energy supplies for its users to support steady socio-economic development. The central reform policies include i) introduction of rental and quick rental power generation as the emergency measures to cope with the power shortage; ii) maximisation of green energy and promotion of its introduction; iii) a legal framework for energy efficiency; iv) fuel diversification in the electricity generation mix; v) revising the energy prices to ensure cost-reflective pricing; vi) encouraging the private companies to enter the energy market; vii) enhancement of imported energy infrastructure and its flexible operation; viii) following a generation plan up to 2023; and ix) export credit agency for financing energy projects.

Moreover, the Bangladesh government formulated extensive energy and power development plan, the Power System Master Plan (PSMP), in 2016, for achieving sustainable development goals in harmonising with economic optimisation.

These initiatives have played a crucial role in strengthening the Bangladesh energy sector over the past 10 years. For instance, there are currently 126 power plants as compared to 27 back in 2009. The net installed electricity generation capacity has increased from 5,272 MW in 2009 to 23,518 MW in 2020, as found in the annual reports of BPDB (Figure 2). Accessibility of electricity has also been increased from 47 percent in 2009 to a whopping 96 percent in 2020. These achievements are aligned with the government's commitment to ensuring access to affordable and reliable electricity by 2021.

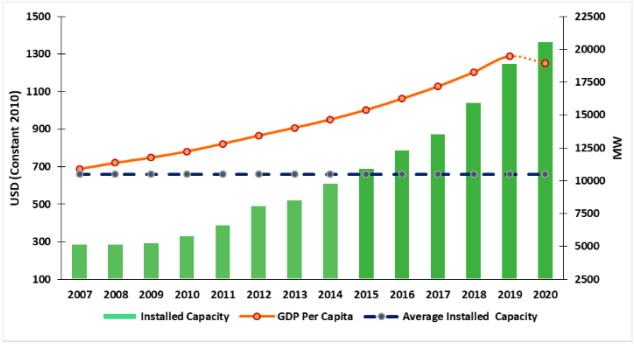

Fig. 2. Overview of installed capacity and GDP per capita in Bangladesh. *(Source: Bangladesh Power Development Board (BPDB, 2020) and World Development Indicators (WDI, 2020))*

Following the oil price shocks in the 1970s, natural gas became the energy of choice in Bangladesh until 2008. Available evidence suggests that the proven recoverable reserve of natural gas in Bangladesh is expected to last till 2031 if the current extraction rate does not change. Given this background, the Bangladesh government attaches high priority to Liquefied Natural Gas (LNG) based power generation as LNG imports can fill the demand and supply gap. Bangladesh now has two Floating Storage and Regasification Units (FSRUs) with a total capacity of 7.5 Million Tonnes per Annum (MTPA) of LNG. The country is also building a land-based terminal that can further handle 7.5 MTPA of LNG, expected to be ready in five years. By 2041, the share of natural gas/LNG will be 35 percent in the electricity generation mix.

There have been suggestions for using coal, as it has been one of the vital resources for electricity generation worldwide. At present, the global average of coal usage in the fuel mix is 41 percent, whereas Bangladesh uses only 2.36 percent. The government aims to steadily increase coal share by up to 35 percent by 2041 and reduce the pressure from liquid fuels. Also, initiatives have been taken for implementing a good number of mega projects such as Matarbari Ultra Super Critical Coal-Fired Power Plant, Payra Thermal Power Plant, and Maitri Super Thermal Power Plant in Rampal to ensure energy security in the future.

Since nuclear power is also one of the cheapest options for generating electricity worldwide, nuclear power generation is also included in the Bangladesh government's agendas to meet the rapidly increasing demand for electricity. It is assumed that the first 1,200 MW nuclear power plant is to start its operations by 2024. Bangladesh's government is also aware of the

development of legal systems and human resources relating to international cooperation and nuclear power, thus, prudently addressing the issues. It is expected that the share of nuclear power will be around 10 percent in 2041.

The use of liquid-fuel in the energy sector started increasing rapidly from the introduction of rental/quick rental (QR) companies. The use of imported High-Speed Diesel (HSD) and Furnace Oil (FO) had increased from around 5 percent in 2009 to 32 percent in 2019. The total cost of imported petroleum products has also increased almost 2 times in the previous 10 years.

Using QR power plants is a well-established choice across the world to resolve the power crisis urgently. There did not seem to exist any better solutions to the problem at that time in Bangladesh. However, the Bangladesh government is now thinking about gradually phasing out the QR power plants and looking into alternative fuels for electricity generation. According to the generation mix of 2041, the share of liquid fuel will be only 5 percent.

Bangladesh's government targets 15 percent of the projected demand of 2041 by importing electricity from neighbouring countries. Thus, regional cooperation will help ensure energy security in the future. At present, Bangladesh mainly imports 1,160 MW of electricity from India besides its generation.

The prospect of renewable energy in Bangladesh is bright, particularly for solar (Table 1) due to the high solar radiation (4.0 to 6.5 kWh/m²/day). Bangladesh is recognised as one of the first countries in the world to implement Solar Home Systems (SHSs) in reaching consumers outside the national grid (Off-grid) or in places where the grid connection is delayed. Almost 18 million people are getting access to electricity from SHSs in Bangladesh.

However, due to the existing market barriers, renewable energy will supplement conventional energy production in the immediate future [23]. In 2018 and 2019, renewable energy shares were 2.66 percent and 2.85 percent in the electricity generation mix, respectively, far behind the world standard and the target set by National Renewable Energy Policy (NREP) 2008. The government has also completed wind mapping in 9 spots and plans to generate 1,100 MW of electricity from wind power by 2021.

Table 1: Renewable energy by type in 2019.

Renewable Sources	On-grid (MW)	Off-grid (MW)	Total (MW)
Solar	81.22	318.16	399.38
Wind	0.90	2.00	2.90
Hydro	230.00	0.00	230
Biogas	0.00	0.63	0.63
Biomass	0.00	0.40	0.40
Total	312.12	321.19	633.31

Source: Sustainable and Renewable Energy Development Authority (SREDA, 2019).

3. ECONOMIC IMPACT OF COVID-19 IN BANGLADESH

The Covid-19 pandemic has made a massive shutdown in all types of business activities. The rapid spread of the virus has also caused a substantial reduction in all forms of economic activities worldwide. According to the Asian Development Bank (ADB) projection, this havoc could lead to a global recession like 2008 due to the economic and financial difficulties [24]. The International Monetary Fund (IMF), United Nations Conference on Trade and Development (UNCTAD), and the Organization for Economic Co-operation and Development (OECD) are all projecting significant economic losses in 2020, the decline of being about 1.6 percent, 1.7 percent, and 2.4 percent of global GDP, respectively [23], [25], [26].

Bangladesh is also no exception to this trend. The World Bank has forecasted that Bangladesh's economic growth in 2020 will be between 2.0-3.0 percent, while the IMF projected this to be 3.8 percent [27], [28]. ADB has already projected that this Covid-19 outbreak will reduce about 0.2 to 0.4 percent of Bangladesh GDP [29].

The economy of Bangladesh has already faced the repercussion of this crisis. The nationwide general holiday has halted the economic activities related to national and international trade, transport, remittance and supply chain of foods, informal job sectors, etc. The crisis's shock has already invaded different economic areas, including export outflow, import inflow, tourist arrival, out-migration, and investment flows [15].

Due to the adverse impact of worldwide trade, the global supply chain has also faced interruption. The trade deficit has increased to 17,861 million US Dollars in 2020 due to the decline in exports and imports by 16.9 percent 8.6 percent respectively [30]. About one-fifth of Bangladesh's global imports mainly come from mainland China. A two percent reduction of Chinese exports in intermediary inputs could cause USD 16 million trade loss to Bangladesh [23]. So, this pandemic would surely disrupt the supply chain in Bangladesh's context (Figure 3).

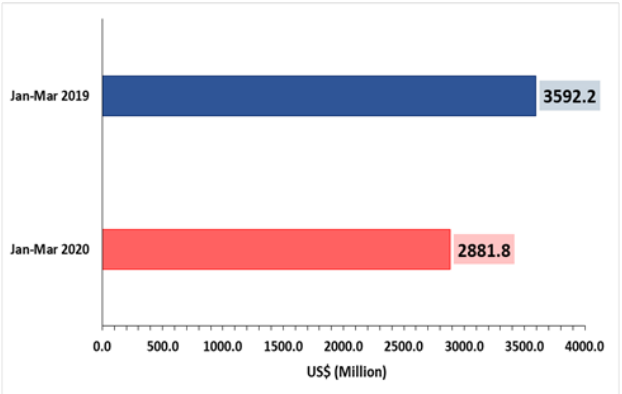

Fig. 3: Import payment to China from Bangladesh in 2019 and 2020. (*Source: Bangladesh Bank, 2020)*

On Bangladesh's export side, the major exporting countries are the worst Covid-19 affected countries globally, such as- the USA, Germany, UK, and Spain. [31] The Covid-19 shock in the western countries would reduce the demand for Bangladesh's Ready-Made Garments (RMG) products by 8 percent, resulting in an overall fall in total export earnings. Figure (4) illustrates that the RMG export (January 2020-March 2020) has reduced by 403 million USD from the equivalent period in 2019.

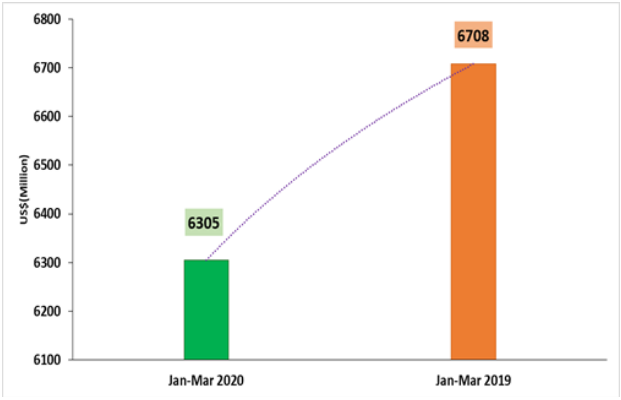

Fig. 4. RMG export from Bangladesh in 2019 and 2020.
(Source: Bangladesh Bank, 2020)

The Covid-19 has already caused a downturn effect on the remittance inflow in Bangladesh. However, Figure 5 shows that remittance inflow has started to increase in recent months after the reduction from January 2020 to April 2020. Most emigrant workers from Bangladesh work in the Middle-East countries, and the global drop in oil prices has caused an adverse economic shock in those countries. However, this is too early to predict the scenario of the future trend amid this pandemic situation. According to the different reports of Bangladesh Bank, much overseas employment of the Bangladeshi workers and professionals has sharply declined in 2020. Many workers have already become jobless, so the recent upward trend may not be sustainable in the future [30].

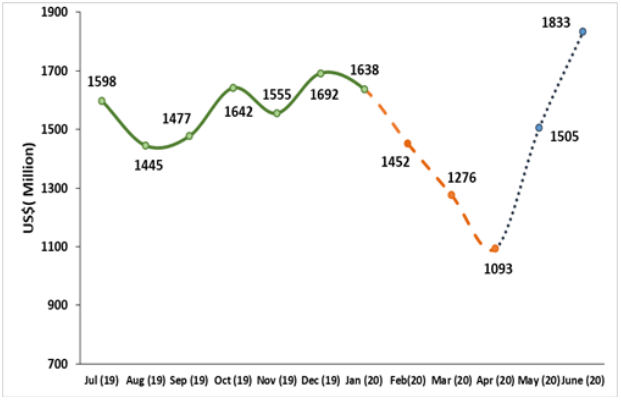

Fig. 5. Remittance inflow in Bangladesh in 2019 and 2020.
(Source: Bangladesh Bank, 2020)

In the Covid-19 era, the tourism sector is one of the worst affected sectors around the world. Every sub-sector related to tourism, such as transport, hotels, sites, and travel agencies, are affected due to this crisis. The World Travel and Tourism Council (WTTC) has estimated that 2.7 trillion USD in revenue could be lost globally in 2020 due to the Covid-19 pandemic [32]. The United Nations World Tourism Organization (UNWTO) [33] has predicted that Bangladesh's tourism industry would face a revenue loss of around 470 million USD in 2020. More than 0.3 million people engaged in the tourism industry may lose their jobs due to the significant drop in Bangladesh's tourism activities and revenues [34].

In an online survey by the Bangladesh Institute of Development Studies (BIDS), it has been found that about 13 percent of people have become unemployed in the country due to the Covid-19 pandemic [35]. ADB [36], by conducting a simulation analysis, has recently shown that if Bangladesh faces larger contamination, then agriculture and mining, manufacturing, and transport sectors might see 4.32 percent, 3.92 percent, and 4.57 percent job losses, respectively.

From the Labour Force Survey 2016-17 of the Bangladesh Bureau of Statistics (BBS), it has been revealed that the youth unemployment rate of 10.6 percent is much higher than the national average of 4.2 percent [37]. The report has also shown a high degree of unemployment among educated youth, as 13.4 percent of unemployed youths have tertiary education, and another 22.3 percent have higher secondary education. Besides, about 82 percent of employment in Bangladesh is in the informal sector. So, the pandemic is expected to affect the informal sector dreadfully compared to Bangladesh's formal sector.

Moreover, around 87 percent of the Small and Medium Enterprises (SMEs) in Bangladesh operate informally and highly rely on a few important religious and cultural events. So, the Covid-19 related general holiday initiatives have generated tremendous financial loss to these SMEs [15]. The BIDS has shown that the SMEs, especially those from rural and semi-urban areas, have shown that the SMEs are the most sufferers during this pandemic. Comparing with the previous year's revenue data, it has also been highlighted that the average revenue reduction for all SMEs in 2020 is 66 percent [35]. The survey has also revealed that more than three-fourth of the goods produced by the entrepreneurs remain unsold.

The Covid-19 pandemic has also created inflationary pressure in Bangladesh. One of the possible reasons is the increase in out of pocket medical expenses (a type of non-food expenditure), which resulted from a sudden disruption in the domestic and international supply chains for necessary medical equipment (such as masks, test kits, medicines, disinfectant chemicals, etc.) According to the recent Bangladesh Bank report, CPI-based general inflation stood at 5.65 percent in the fiscal

year 2020 compared to the inflation rate of 5.47 percent in 2019 (Figure 6).

Besides, BIDS online survey has shown the expected and significant adverse effects on employment, income, and expenditures of people, especially those from low-income groups in this pandemic situation [35]. About one-fifth of the participants with income less than 5,000 takas have reported that their income was reduced by 75 percent. About one-fourth of the participants with income between 5,000-15,000 takas have reported a reduction by 50 percent relative to last month's pay. The survey has shown that Bangladesh will have 16.4 million new poor in 2020 as the working class income in urban and rural areas has fallen sharply due to the general holiday to stop the Covid-19 pandemic spread.

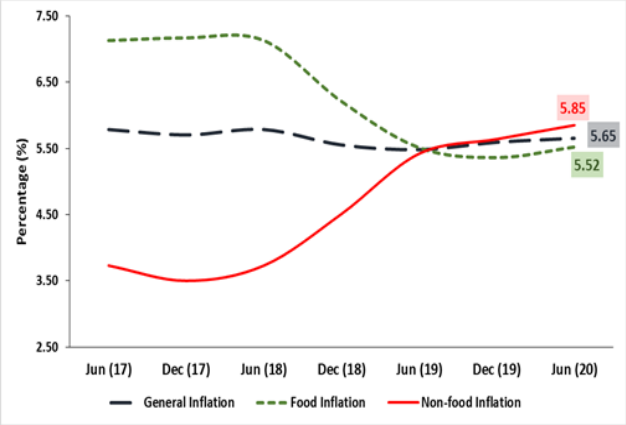

Fig. 6. 12-month average CPI of Bangladesh from 2015 to 2020 *(Source: Bangladesh Bank, 2020).*

In Bangladesh, the majority (more than 80 percent) of the governmental revenue comes from the National Board of Revenue (NBR) sources. According to the Ministry of Finance Statistics (2020), the Government of Bangladesh, both the NBR and non-NBR tax revenues, have experienced negative growth rates of 6 percent and 4.3 percent, respectively, during the second quarter of 2020 compared to the equal period in 2019 [30]. Low revenue mobilisation in the pandemic situation is expected to mount budgetary pressure for the country.

Covid-19 may also severely affect the financial sector of Bangladesh. Private sector credit growth has been declining for a longer time, and in June 2020, credit growth has dropped to 8.6 percent [30]. This pandemic situation will surely disrupt the banks' capacity to give out loans at a massive level.

4. IMPACT OF COVID-19 IN BANGLADESH ENERGY SECTOR: AN EMPIRICAL AND SIMULATION EXERCISE

To observe the Covid-19 pandemic effect on Bangladesh's energy sector, the seasonal electricity demand from 2016 to 2020 is shown in Figure 7. The figure depicts the seasonality features and increasing trend in electricity demand since 2016. However, the situation is different in the case of 2020. The electricity demand in March 2020 is found to be higher than in 2019. However, it has started declining sharply from April 2020, and till June 2020 (at the time of writing this paper), it is still lower than the 2019 level. This is due to the fact that Bangladesh declared a nationwide general holiday on March 24. However, electricity demand is catching up at a high rate because of the relaxation of general holiday measures in the subsequent period, and in June 2020, it is just below the 2019 level.

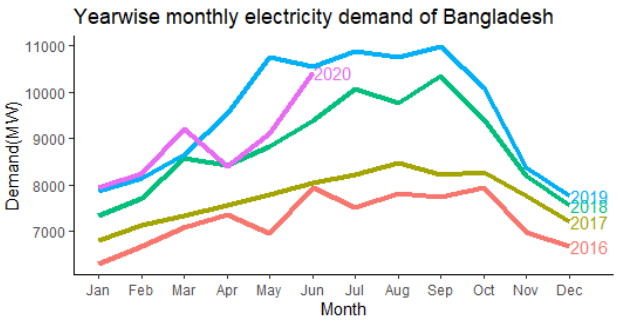

Fig. 7. Comparison of Bangladesh's seasonal electricity demand for 2016, 2017, 2018, 2019, and 2020 *(Source: Bangladesh Power Development Board, BPDB, 2020).*

In this paper, we have used SARIMA (1, 0, 0) (0, 1, 0) [12] model [2] to generate a counterfactual value of electricity demand for Bangladesh during the lockdown period, using pre-general holiday (January 2016 to March 2020) electricity data. The SARIMA (1, 0, 0) (0, 1, 0) [12] model is revealed as the best model in the auto.arima function of R. Instead of traditional Box-Jenkins methodology, auto.arima is a function of forecast package, which uses corrected Akaike Information Criteria (AIC) to select the order of ARIMA models and it uses an algorithm, created by Hyndman and Khandakar [38]. It runs a series of different ARIMA models and chooses the best fitted ARIMA model by corrected AIC.

This counterfactual value of electricity demand is created to see the effect of lockdown on electricity demand in Bangladesh. We can see from Table 2 that general holiday had a significant impact for April, May, and June. Even though the real electricity data was available from April to June, the simulation is done to determine the electricity demand if the situation was normal.

Table 2. Comparison of forecasted electricity demand and real electricity demand (1, 0, 0) (0, 1, 0).

Month	Counterfactual Values	Real Values	Estimated Demand Gap
April	10175.3	8400.9	1774.5
May	11406.3	9097.6	2308.7
June	11229.4	10425.6	803.7

Source: Bangladesh Power Development Board, BPDB, 2020

[2] For more details, see [54]

We have collected the daily data in MW from the Bangladesh Power Development Board. [3] The data are then averaged, summing each month's specific daily data and then dividing it by the number of days of that particular month and converted into mean daily data per month. Therefore, we have avoided the weekly seasonality that stems from the daily electricity data.

SARIMA model was previously used in Bangladesh to forecast the Dengue epidemic's consequences in Bangladesh [39]. Moreover, the SARIMA model's application is also evident in assessing the different pandemic aspects worldwide [40]–[44]. Usage of the SARIMA model to forecast short-run electricity demand is very prevalent in literature [45]–[47].

We have then used data from January 2016 to June 2020 to accommodate the effect of general holiday in our SARIMA model and forecast the electricity demand for the next 24 months. In this case, the SARIMA (1, 0, 0) (1, 1, 0) [12] model is found to be the best fit model in auto.arima function. The forecasted values are presented in Table 3. Figure 8 is drawn from the values of Table 3, where dark blue shades show an 80 percent confidence level, and light blue shades show a 95 per cent confidence level**.** The validity of the model has been checked by the Ljung-Box test and found that the p-value is 0.14. It means residuals are white noise only, and this model perfectly fits this time series data. Figure A1 in Appendix shows the residuals of this model.

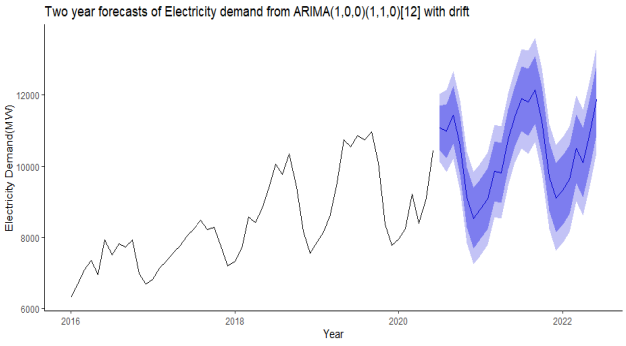

Fig. 8. Two-year forecast for electricity demand of Bangladesh. (*Source: Authors' calculation)*

Following Amin [47] and Amin and Marsiliani [17] [4], we also present a Dynamic General Equilibrium (DGE) model for Bangladesh economy to capture the long-run consequences of the Covid-19 towards Bangladesh energy sector and economy [48]. DGE models have become popular days among researchers to analyse the sectoral changes within an economy caused by sudden shocks like the Covid-19 [49]. These models can provide meaningful insights into the policymakers through the simulation exercises in a general equilibrium framework.

References [48], [50] argue that the DGE models are more appropriate than the other macro models and input-output models to find the long-run steady-state scenarios from any exogenous shocks. However, it is worth noting that they are not proven to be useful to capture the short- run changes in the economy. Accordingly, we have employed the SARIMA model in this paper to capture the short-run scenarios for policy reasons.

The use of general equilibrium models to examine adverse economic effects from the health outbreaks is not an old phenomenon [51]. Recently, using a hybrid of a CGE model and a Dynamic Stochastic General Equilibrium (DSGE) model, [52] have revealed that depending on the epidemiological scenario considered, the GDP loss can range from 283 to 9,170 billion USD worldwide. Moreover, [53] have found that Covid-19 caused global GDP to fall by 2 percent due to a decline in trade services, increased trade costs, and sub-optimal labour and capital use.

Following [17], the firm's production function is described by a Cobb-Douglas production function.

$$Y_t = A\, k_t^{\alpha} (V.l_t^{\gamma}) g_t^{1-\alpha-\gamma} \tag{1}$$

Where α and γ is the share of capital input (k_t) and labour input (l_t) in aggregate output, respectively, and 1-α- γ is the share that goes to the energy input (g_t). V is the lockdown parameter where it takes the value of 1 in the benchmark model with no general holiday scenario.

Households consume electricity (e_t), standard consumption goods (c_t), and leisure $(1\text{-}l_t)$ and receive utility as follows.

$$u_t = \varphi\, ln\, [\theta c_t^{\rho} + (1-\theta) e_t^{\rho}]^{\frac{1}{\rho}} + (1-\varphi) ln\, (1-l_t) \tag{2}$$

Here, φ represents the share of consumption in the household's utility, where φ ε (0, 1). θ is the share of standard consumption in the household's aggregator, where θ ε (0, 1). The utility function shows the commonly assumed properties like u_c >0, u_{cc} <0, $\lim_{C\to 0} = \infty$ and $\lim_{C\to\infty} = 0$.

The price of energy used in the economy, P_t, is exogenously given. As energy is used both by the consumers and the producers in this model, the economy's resource constraint for period *t* is given by:

$$Y_t = c_t + i_t + P_t\, (e_t + g_t) \tag{3}$$

The Lagrangian to the planning problem can be written as follows.

$$\begin{aligned} L = & \sum_{t=0}^{\infty} \beta^t \Big(\varphi\, log\, [\theta c_t^{\rho} + (1-\theta) e_t^{\rho}]^{\frac{1}{\rho}} \\ & + (1-\varphi)\, log(1-l_t) \Big) + \lambda_t [A\, k_t^{\alpha} (V.l_t^{\gamma}) g_t^{1-\alpha-\gamma} \\ & + (1-\delta) k_t - c_t - P_t\, (e_t \\ & + g_t)] \end{aligned} \tag{4}$$

[3] https://www.bpdb.gov.bd/

[4] For more details, see [48].

Where β is the discount factor, λ_t is the Lagrange multiplier, and the function is maximised for c_t, k_{t+1}, e_t, l_t, g_t, and λ_t.

We calibrate and simulate the model for the Bangladesh economy for quarterly frequency and then compare the steady-state values of the benchmark model's key variables with a policy experiment of 50 per cent reduced labour due to isolation associated with the general holiday. It is worth noting that general holiday caused a persistent labour shortage, and the supply shock would reduce the output. During the general holiday, the households also stayed at home, which adversely affected the income level and lower the demand (demand-side effect). Both the demand and supply-side shocks argue that the economy goes through a large contraction with reduced electricity and energy demand due to the lockdown.

We run the program Dynare version 4.6.1 to solve and simulate the model. The structural parameter values are listed in Table A1 in the Appendix. Our results reveal that due to the Covid-19, Bangladesh's GDP growth rate would be around 4.5 percent in the long-run. These results are consistent with the IMF and WB predictions, as discussed in Section 3. We further simulate that the steady-state electricity demand and standard consumption values would fall by 8-10 percent and 6 percent, respectively. We check the robustness of these results with varying lockdown parameters (V=0.20 and V=0.33) and find almost similar results.

Table 3. Forecasted electricity demand from SARIMA (1, 0, 0) (1, 1, 0) [12] model.

Month	Point Forecast	Lo.80	Hi.80	Lo.95	Hi.95
Jul-20	11072.8	10452.1	11693.5	10123.6	12022.1
Aug-20	10990.6	10240.2	11740.9	9843.0	12138.1
Sep-20	11440.4	10637.3	12243.6	10212.1	12668.8
Oct-20	10592.2	9765.8	11418.6	9328.4	11856.1
Nov-20	9135.1	8298.2	9972.0	7855.2	10415.1
Dec-20	8542.2	7700.5	9383.9	7254.9	9829.4
Jan-21	8788.9	7945.0	9632.9	7498.3	10079.6
Feb-21	9094.4	8249.5	9939.4	7802.2	10386.7
Mar-21	9863.4	9018.0	10708.8	8570.4	11156.3
Apr-21	9818.9	8973.3	10664.6	8525.7	11112.2
May-21	10742.9	9897.2	11588.6	9449.5	12036.3
Jun-21	11391.1	10545.3	12236.9	10097.6	12684.6
Jul-21	11893.4	10978.5	12808.3	10494.2	13292.6
Aug-21	11797.6	10852.6	12742.7	10352.3	13243.0
Sep-21	12144.0	11185.3	13102.7	10677.8	13610.2
Oct-21	11284.6	10319.7	12249.5	9808.9	12760.3
Nov-21	9713.9	8746.2	10681.7	8233.9	11194.0
Dec-21	9116.0	8146.9	10085.1	7633.9	10598.1
Jan-22	9328.6	8358.9	10298.2	7845.6	10811.6
Feb-22	9630.1	8660.1	10600.0	8146.6	11113.5
Mar-22	10490.9	9520.8	11461.0	9007.3	11974.6
Apr-22	10101.1	9130.9	11071.2	8617.3	11584.8
May-22	10923.4	9953.2	11893.5	9439.6	12407.1
Jun-22	11875.9	10905.7	12846.1	10392.1	13359.6

(*Source: Authors' own calculation)*

5. CONCLUSION AND POLICY RECOMMENDATIONS

Given our results of lower GDP and reduced electricity demand, we argue that Bangladesh may reconsider its energy generation policy towards more efficient and sustainable energy production and distribution. The Bangladesh government previously adopted coal-based mega power plants to meet the historical energy crisis associated with the shortage of electricity supply. Considering the growing public concerns, the government can reduce the dependency on coal use in the fuel mix capacity for future electricity generation.

This reduced demand for electricity and the over-generation capacity may also coexist for a couple of years more. Therefore, policymakers may take a planning model in which decisions are taken both proactively and reactively, and the organisational

environment should be predictable and stable [47]. Due to the adverse impact on the environment for utilising finite energy resources, many developed and developing countries are now inclined toward various forms of renewable energy like solar power, wind power, bioenergy, hydropower, etc. [15].

We argue that a pragmatic intra- and inter-sectoral shift in resource allocation in the energy sector and a review of the power sector master plan is needed for the Bangladesh energy sector. The energy sector's ADP allocation shows that the renewable energy sector was somewhat overlooked while formulating energy policies [13]. The ADP share of renewable energy lies around 4-9 percent for a long time. So, the government can consider re-evaluating the effectiveness of the mega projects of electricity from fossil fuels in the ADP and diversify a part of the resources allocated for these mega projects towards the renewable energy sector. Given our results, we also highlight that government may start phasing out QRs by not renewing the contracts further and bringing changes in the existing agreements.

We also recommend the policymakers to link up our energy system and exploit the synergies enabled by an Integrated Energy System (IES). The IES can ensure a hybrid solution to the existing energy options for generating future electricity sources to reduce fossil-fuel dependency in Bangladesh. A diverse range of energy efficiency programmes could be implemented for the country's future energy security. The government could also take the necessary steps to develop efficient transmission and distribution mechanisms for uninterrupted electricity supply.

Our model can be generalised by introducing different types of households, firms, a detailed disaggregated energy sector, and a government sector to review Covid-19 energy policies in Bangladesh carefully.

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APPENDIX A

Table A1. The parameter values.

β, discount factor	0.96
α, capital share of output in the production function	0.31
γ, labour share of output in the production function	0.65
δ, depreciation rate	0.025
φ, the share of consumption in the household's utility	0.41
θ, the share of standard consumption	0.8
σ, the CES parameter of household's utility function	-0.11
V, lockdown parameter	1 (no lockdown) 0.5 (lockdown)

Source: Bangladesh Household Income and Expenditure Survey (2010), Bangladesh Bureau of Statistics (BBS, 2015).

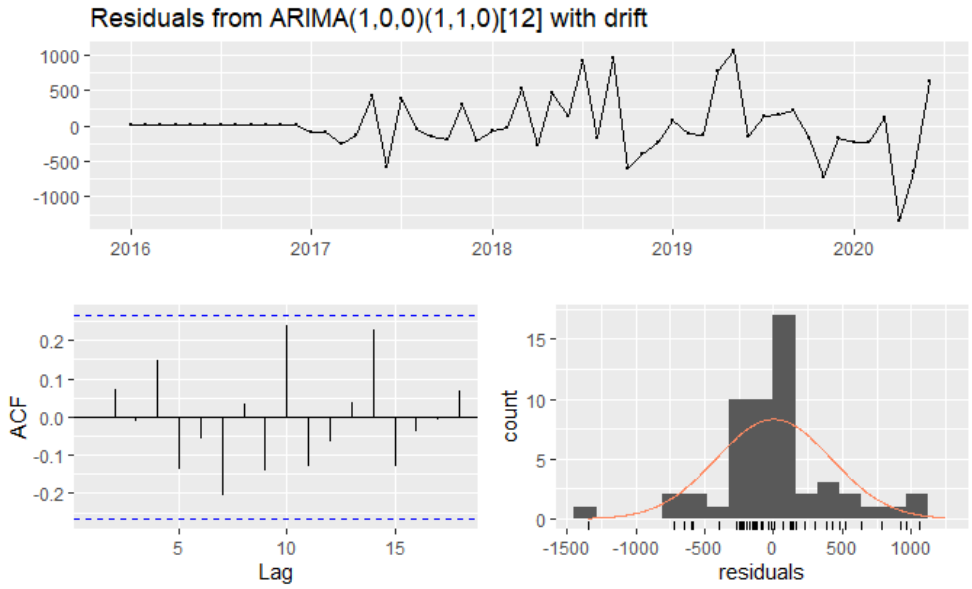

Fig. A1. Residuals from ARIMA (1,0,0) (1,1,0) [12] (*Source: Authors' own calculation)*