

# SUSTAINABLE ENERGY SECURITY FOR ECONOMIC DEVELOPMENT: TRENDS AND CHALLENGES FOR BANGLADESH

*Shahi Md. Tanvir Alam\**

## *Introduction*

Energy development is an integral part of enhanced and sustainable development. The fact that the expanded provision and use of energy services is strongly associated with economic development highlights how important energy is as a causal factor in economic development; however, energy development competes with other opportunities for scarce capital and opportunities for policy and institutional reform. Energy plays a pervasive role that accelerates the socio-economic progress of a nation. Almost every economic activity involves energy as an input and securing sustainable sources of energy is an important strategic

---

\*Shahi Md. Tanvir Alam works as an Assistant Director at the Bangladesh Energy Regulatory Commission (BERC). He is a recipient of the Tempus Public Foundation scholarship and is currently a Ph.D. candidate in the Doctoral School of Economics and Business Administration in the University of Szeged (Hungary). Mr. Tanvir received both his undergraduate and post-graduate degrees in economics from Khulna University and Jahangirnagar University, respectively, in Bangladesh, along with his M.B.A. degree from Khulna University. The author has published internationally, and his research interests include energy and economic development, expansion of renewable energy, auction designing for renewable energy, and energy pricing.

The author would like to acknowledge Professor Mohammad Amzad Hossain, the then-Head of the Economics Department, Jahangirnagar University, Savar, Dhaka, Bangladesh, who guided him on this research. The author extends his gratitude for the Professor's support in the publication process. Additionally, the author extends his thanks to the Bangladesh Power Development Board (BPDB), the Ministry of Power of the Government of Bangladesh, and the Planning Commission, Bangladesh, for providing time and data-related support.

*The Journal of Energy and Development*, Vol. 46, Nos. 1-2

Copyright © 2022 by the International Research Center for Energy and Economic Development (ICEED). All rights reserved.

priority for most countries. This is true in the case of Bangladesh, which is one of the fastest growing economies in the world along with having a very large population in excess of 160 million citizens.

Bangladesh has been deemed a “New Asian Tiger” and has been identified by Goldman Sachs as one of the “Next Eleven” countries, which are 11 nations with the high potential of becoming among the world’s largest economies in the 21st century along with Brazil, Russia, India, China, and South Africa (BRICS). Bangladesh has exhibited constant gross domestic product (GDP) growth, net power generation growth, and growth in industrial production over the past few years.

Bangladesh’s GDP has been robust in recent years. According to the Asian Development Bank, the nation’s GDP growth rate is expected to be 6.8 percent in 2021 and 7.2 percent in 2022. Historically, the economy was dominated by the agricultural sector, but that trend has been challenged due to increased urbanization and today 45 percent of Bangladeshis are employed in the agriculture sector. Moreover, the economy has experienced increased diversification. More than half of the nation’s GDP is generated through the services sector. Additionally, the rapid growth of urbanization has fueled the stable economic growth seen in recent years and has created a huge increase in energy demand. These shifts in GDP have been accompanied by a changing demand in energy composition, which has highlighted the need for ensuring and prioritizing energy security.

Energy demand and supply nurtures all aspects of life within the ecological world. The structure of energy is a local as well as a global issue, where nations need a deeper understanding of the broader implications of their actions. The energy landscape of today is significantly distinct from a decade ago and is expected to appear substantially different within the next decade with the emergence of new technologies to harness renewable energy and climate change policies. There is no doubt that energy policy is vital for each nation’s economic development, including Bangladesh, which aims to be designated as a “middle-income” nation by 2021 and needs to successfully manage its energy situation in a sustainable manner.

According to Gro Harlem Brundtland, the former Prime Minister of Norway, sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Energy security means energy availability in adequate quantities and at affordable prices, which are prerequisites to sustain targeted levels of economic growth and supporting desired levels of social development. Bangladesh is eager to implement successful sustainable development and energy security policies that will enhance its socio-economic levels now and for future generations.

Energy security effects many aspects of a country’s economy and is particularly important for agricultural production and, thus, guaranteeing food security. Additionally, industrial production is not possible without the consistent supply of electricity or natural gas. Energy security not only is an issue of concern for public policy makers but also is a salient factor for financial decision makers. Global

investors take into consideration which countries have better energy security and stronger energy infrastructures that ultimately facilitate and stabilize economic growth and bolster investment opportunities. In general, developed countries have higher growth rates, in part, because they have access to greater energy sources or more efficient energy management systems whereas poorer countries can have fewer energy resources and less secure energy systems, such as underinvestment or inadequate energy infrastructure.

All nations must cope with the issue of energy security to one extent or another. As a result, securing both domestic and global sources of energy supplies are important. However, for the countries that are highly dependent upon imported energy sources, such as fuels, and from a limited number of suppliers, the issue of energy security is even more critical. Fluctuations and volatility in international energy markets can have a significant and detrimental effect on net energy-importing nations. Last but not least, political instability in energy-producing states can disrupt the global energy supply, which can be particularly problematic for developing countries that are net energy importers.

In this article, the focus is on the case of Bangladesh and how meeting its energy security is part of achieving sustainable development. The article is laid out as follows: we begin with a literature review and discussion, which is followed by an overview of the energy sector in Bangladesh. Next, the importance of the natural gas sector and the country's energy mix will be presented. Subsequently, we will discuss three trends in Bangladesh: GDP growth, net electricity generation, and industrial production growth. A methodology section follows that explains our research design, data collection, and sampling along with our hypothesis development. Then we present the data analysis and results, which includes our variable lag selection, stationarity check, test for co-integration, and vector auto-regression (VAR) results. We conclude with our findings and recommendations.

### *Literature Review and Discussion*

Having a secure energy supply is crucial for the well-being of a nation's citizens as well as the state of its economy. Energy security became a major global concern after the 1973 oil crisis. Energy security has many aspects; it can be defined as the uninterrupted supply of energy from available sources at an affordable price. Long-term energy security necessitates the timely investments in and access to adequate supplies of energy—both in terms of quantity and quality—in line with fostering economic development, meeting demand, and balancing environmental needs. On the other hand, short-term energy security focuses on the ability of the energy system to react promptly to sudden changes in the supply-demand balance.<sup>1</sup>

When energy is readily available, affordable, and provided from a reliable source (now and in the future) at a stable price without vulnerability to economic

and political disruptions; energy security is ensured. There are some factors that support increased energy security. Diversification in power generation capacity and safeguarding the energy supply available to all at a reasonable price are two of the most salient aspects of energy security. In addition, a significant amount of investment, developed infrastructure, and a well-trained workforce in the energy sector are needed for secure energy transmission and distribution.<sup>2</sup>

Another issue of increasing importance for global energy security is addressing climate change and reducing greenhouse gas (GHG) emissions. Yet the issue of how much energy consumption must be reduced and by which countries in order to slash global GHG emissions is a contentious one. It has been argued that it is the ethical responsibility of developed countries to reduce their energy consumption through energy efficiency and conservation as part of the global effort to reduce GHG emissions, especially because many of these nations are the largest energy consumers and GHG emissions emitters. While climate change policies may be determined at a national level, one should not lose sight of the fact that it is individuals that are actually bearing the consequences of these policies. Developing countries have different obligations regarding their energy consumption patterns. To improve their citizens' quality of lives, these nations should support policies that will result in the greater use of modern energy sources and also support improved energy efficiency and conservation. To date, some of the ethical implications and energy justice issues regarding changes in energy consumption patterns in response to GHG emission-reducing policies have received less attention.<sup>3</sup>

The existing literature finds that there are two primary ways of reducing energy consumption: energy efficiency and energy conservation. Energy efficiency refers to doing the same amount of work or producing the same amount of goods or services with less energy, while energy conservation refers to using less energy regardless of whether energy efficiency has changed.

Sustainable development relies on appropriate energy use. On the one hand, energy use can accelerate socio-economic progress and economic productivity, but, on the other hand, it contributes to climate change, biodiversity loss, often adverse changes in the ecosystem, and can detrimentally affect human well-being. Thus, it is very important to understand how to ensure the maximum amount of access to affordable and efficient energy without harmful social and environmental impacts. There are a number of energy policy options that have been suggested that could reduce the rate of global environmental degradation, such as caps on energy use. Energy use caps could result in fewer natural resources being consumed across the globe, which would then ultimately lead to a rise in demand for lower energy-input products and services. Moreover, due to this process, labor would become more competitive, and more jobs would be created in the different sub-sectors of the economies around the world. Above all, this could lead to a healthier ecosystem.<sup>4</sup>

Energy consumption and its efficiency often are associated with a country's competitiveness in the international arena, especially in terms of consumption in the industrial sector. Moreover, there are tremendous implications for the increased use of renewable energy in changing the competitiveness of individual nations and having an aggregate beneficial outcome at the worldwide level.<sup>5</sup>

Despite the desirability of renewable energy sources and the decline in their prices in recent years, there are still some comparative economic challenges faced by some renewable energy sources. In the past, size, market penetration, and commercialization have been barriers for renewable sources. For example, some small- and medium-sized wind power plants require more investment compared to larger ones. Indeed, for sustainable development, while renewable energy sources are prudent choices, some ethical issues are also attached to their use, including access and affordability.<sup>6</sup>

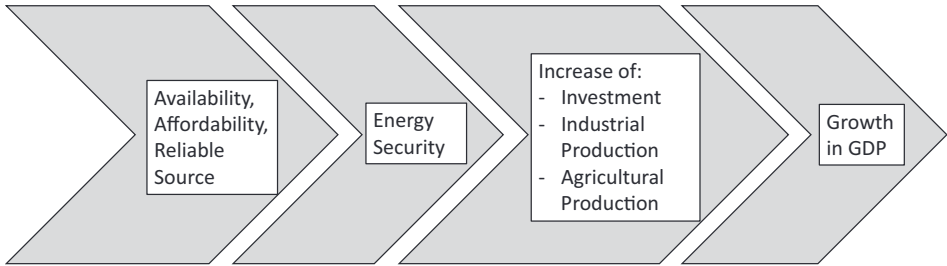
The landmark research by S. Schurr remains one of the best and most convincing examples of the potential for a positive synergy between energy development and broader economic development for industrial societies.<sup>7</sup> Schurr argued that apart from changes in the composition of economic activity toward less energy intensive goods and services, and an increase in the thermal conversion efficiency of energy in the economy, observed productivity increases for non-energy production factors partly resulted from increased use of more flexible energy forms (liquid fuels and especially electricity), through which "the discovery, development, and use of new processes, new equipment, new systems of production, and new industrial locations" were enhanced.<sup>8</sup>

A critical element of Schurr's argument is that changes in the quality of energy services drive broader economic productivity, apart from the physical availability of energy. These arguments are further developed in a subsequent portion of this paper. In large part, however, the literature on energy and development—including the literature relevant to lower-income countries—focuses on how energy demand is driven by economic development.<sup>9</sup>

A fundamental tenet of economic theory is that short of some hypothetical saturation point, an increment to any factor of production implies a *ceteris paribus* increase in output. More is always more. Therefore, our theoretical discussion seeks to highlight ways in which the contribution of increased energy availability might somehow disproportionately stimulate development. This discussion is motivated partly by recent developments in the theory of endogenous economic growth with increasing returns, though that literature has said little about energy per se.<sup>10</sup>

Overall, energy security drives the growth of a country by facilitating its production. Every 1-percent growth of GDP is estimated to lead to a growth of 1.4 percent in demand for electricity in a typical developing country. For a 5-percent to 6-percent typical annual economic growth rate, this would imply a need for close to a 7-percent to 8-percent growth in electricity supply.<sup>11</sup> Figure 1 provides a visual representation of the influence of energy and economic growth and its path.

Figure 1  
 DIAGRAMMATIC PRESENTATION OF THE INFLUENCE OF ENERGY ON ECONOMIC GROWTH



Source: Author's creation.

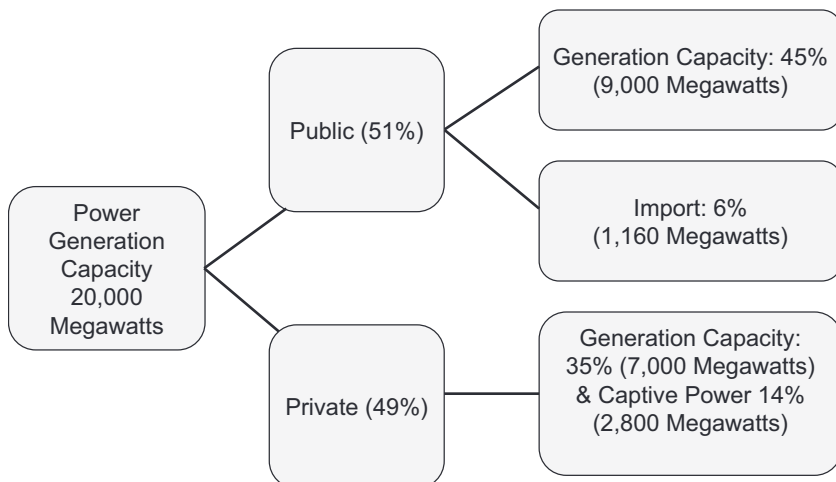
### *Overview of the Energy Situation in Bangladesh*

A sustainable energy supply is needed for Bangladesh to prosper in the coming decades. As a result, if there is not a consistent energy supply, there will be severe adverse consequences for the nation's economic as well as social development. The government of Bangladesh (GOB) is committing resources to developing domestic sources of energy. Bangladesh's current energy requirements are met by a variety of different energy sources including natural gas, oil, and coal; however, the country is dependent on energy imports, making its economy vulnerable to any shocks coming from the international market.

**The Power Sector in Bangladesh:** The goal of the country's power sector is to provide uninterrupted and quality electricity to all at an affordable price by 2021. Bangladesh's power market is horizontally integrated. Electricity is distributed by six distribution companies, namely, the Bangladesh Rural Electrification Board (BREB) through its 80 Palli Biddut Samity (PBS), the Bangladesh Power Development Board (BPDB), Dhaka Power Distribution Company Limited (DPDC), Dhaka Electric Supply Company Limited (DESCO), Northern Electricity Supply Company Limited (NESCO), and West Zone Power Distribution Company Limited (WZPDC). According to the report of the Power Division of the GOB (with information up to December 2018), the public sector generated 51 percent of total power generation and the private sector was responsible for 49 percent of the total power generation (i.e., 20,000 megawatts).<sup>12</sup> The total electricity consumers were 31.8 million, per-capita energy generation was 464 kilowatt hours, and access to electricity was 91 percent of the total population.<sup>13</sup> Figure 2 offers an overview of Bangladesh's power generation.

According to the Statistics from the Power Division for 2018, the greatest amount of power was being generated from natural gas and renewable energy

Figure 2  
 BANGLADESH: POWER GENERATION STATISTICS (TO DECEMBER 2018)



sources generated the least amount. Further, 6.69 percent of power (approximately 1,338 megawatts of power) is being imported from India. According to the Statistics of Power Division for 2018, the maximum quantity of electricity is being consumed by domestic users.<sup>14</sup> Additionally, according to the analysis of the Bangladesh Energy Regulatory Commission (BERC), which is the independent regulatory authority of the country’s energy sector, the per-capita energy generation was 350-kilowatt hours as of May 2018.<sup>15</sup> Further, as per the World Bank’s 2014 report, per-capita energy usage in Bangladesh was 222.221 kilograms of oil equivalent, whereas in 2018 it was 452.22 kilograms of oil equivalent. Due to greater energy imports and increased energy generation, the nation’s per-capita energy usage has increased.

**The Natural Gas Sector in Bangladesh:** A central objective of Bangladesh’s gas sector is to provide energy for sustainable economic growth and maintain the country’s energy security. Bangladesh’s natural gas demand is expected by some independent analysts to grow by around 6 percent annually over the next two decades. In addition to power generation, other potential uses for natural gas in Bangladesh include petrochemicals, compressed natural gas (CNG) for vehicles, and fertilizer. Headed by PetroBangla, natural gas exploration and production projects are undertaken by BAPEX, Bangladesh Gas Fields Company Limited (BGFCL), Sylhet Gas Fields Limited (SGFL), and international oil companies (IOC). The Gas Transmission Company Limited (GTCL) transmits gas to the distribution company. The six distribution companies (Titas Gas, Bakhrabade Gas, Jalalabad

Gas, Karnaphuli Gas, Poschimanchol Gas, and Sundarban Gas) distribute gas to end consumers. Despite the country's high use of natural gas, it possess few proven reserves. According to the 2018 *World Energy Outlook*, Bangladesh holds approximately 0.10 percent of the world's proven natural gas reserves, which is equivalent to seven times its annual consumption. However, because the power generating sector of Bangladesh largely depends on natural gas and the country's reserves are predicted to be depleted by the year 2028, the nation's energy security is jeopardized (table 1).

Further complicating the matter is that domestic gas production is on a decline, so the government of Bangladesh has started to import gas to keep pace with demand and meeting its economic development needs. Securing adequate gas supplies to meet demand is a pressing issue for the government. As a first step, the government has signed 15-year agreements with Qatar Gas and Oman Gas to import liquefied natural gas (LNG). The government has established a regasification point at Chottogram. After being regasified, the LNG is being blended with domestic natural gas and transmitted through pipeline. The majority is used for power generation. The captive power, industrial, and domestic sectors use approximately 16 percent of the 2,750 million cubic feet of gas per day (mmcf).

**Aspects of Bangladesh's Primary Energy Mix:** To secure Bangladesh's energy security, the country needs to manage its primary energy mix, which is currently highly dependent upon hydrocarbons. The country has limited domestic energy reserves, making renewables a very attractive option for development. According to an analysis by BERC, the primary sources of energy in Bangladesh

Table 1  
BANGLADESH: NATURAL GAS SECTOR AT A GLANCE<sup>a</sup>

Factor	Quantity
Number of gas fields in Bangladesh	27
Number of gas fields under production	19
Number of gas wells under production	110
Current gas production capacity	2,750 mmcf
Supply of LNG	320 mmcf
Current daily gas demand	4,000 mmcf (approximately)
Current daily gas supply	3,070 mmcf
Number of gas consumers	4.18 million
Estimated gas reserves (proven & probable)	27.77 Tcf
Total gas production since inception	15.22 Tcf
Remaining gas reserves (proven & probable)	12.54 Tcf

<sup>a</sup>Tcf = trillion cubic feet, mmcf = million cubic feet of gas per day; LNG = liquefied natural gas.

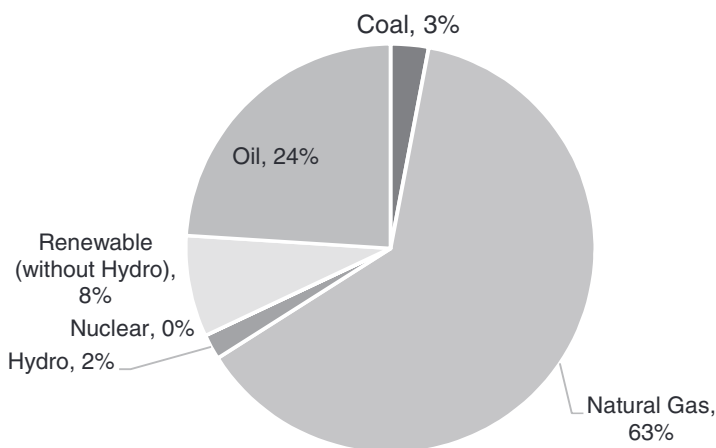
Source: Bangladesh Oil, Gas and Mineral Resource Corporation (PetroBangla), *On the Issue of Gas Production* (Dhaka: PetroBangla, 2018).

are natural gas, condensate, coal, oil, imported power, hydro power, and other renewable sources. BERC’s evaluation suggests total energy in Bangladesh is 73,460,967.699 tons of oil equivalent as of fiscal year 2016-2017 and the energy expenditure per person is U.S. \$226.56.<sup>16</sup> During the same period in the United States, the energy expenditure per person was U.S. \$3,211. Figure 3 gives an overview of the primary energy mix for Bangladesh.

Bangladesh’s heavy dependence on natural gas and oil in its energy mix is problematic for its energy security. Increasing renewables and better diversifying its primary energy mix would greatly enhance the nation’s security, promote sustainable economic development, and have positive environmental effects. Switching to a lower-carbon primary energy mix would have many additional advantages for the country, which is very vulnerable to the negative effects of climate change. It has been estimated that by 2050, one in every seven people in Bangladesh will be displaced by climate change. Up to 18 million people may have to move because of sea level rise alone. Even though Bangladesh on its own cannot address global climate change, enacting policies that support a primary energy mix that is lower in GHG emissions would be beneficial for its overall security.

**GDP Growth Trends in Bangladesh:** Bangladesh has maintained consistent growth and never defaulted on its internal or external debt obligations despite the Asian and global financial crises, numerous political upheavals, and countless

Figure 3  
PRIMARY ENERGY MIX SCENARIO FOR BANGLADESH  
(in percentages)



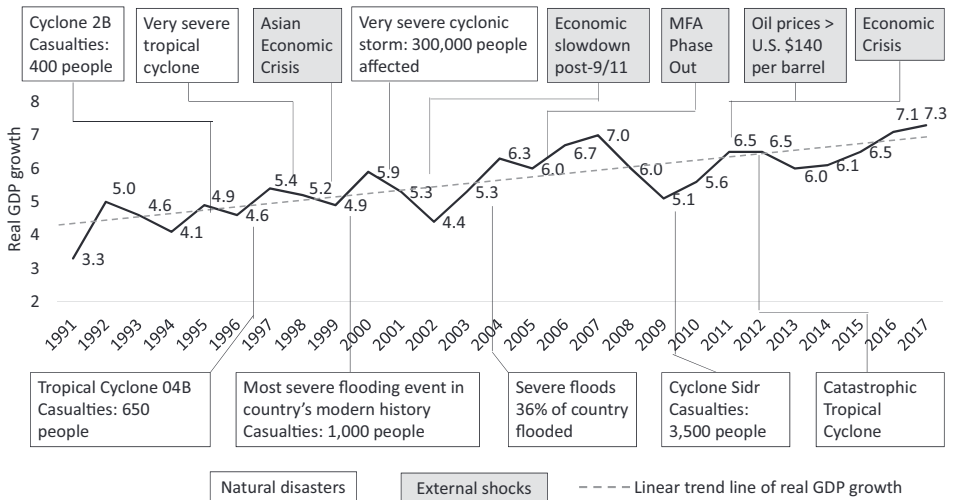
Source: International Energy Agency (IEA), *On the Issue of Energy Efficiency* (Paris: IEA, 2018) and World Energy Outlook (WEO), *On the Issue of Global Energy Trend* (Paris: WEO, 2018).

natural disasters. This consistency is practically unrivaled among countries of a similar level of development. For example, in 2011 there was an economic crisis; yet there was still a real GDP growth of 6.50 percent. Even in the wake of the 2012 catastrophic cyclone, the real GDP growth rate stayed consistently strong at 6.50 percent. Figure 4 illustrates the country’s resiliency in the face of significant shocks both economic and in terms of natural disasters.

**Net Electricity Generation Trends in Bangladesh:** The net electricity generation in Bangladesh has improved greatly since the nation’s independence in 1971. Back in fiscal year 1970-1971, the net electricity generation was a mere 883 gigawatt hours (GWh). As it is highlighted in table 2, by fiscal year 2009-2010, net electricity generation was 29,247 GWh and in fiscal year 2016-2017, generation had reached 57,276 GWh.

The government has allocated substantial amounts of funds in its Annual Development Program (ADP) for continuously improving the power sector through implementing various projects undertaken by different organizations and entities. In 2009-2010, the ADP allocated BDT. 2,676.57 crore for implementing 47 projects in the power sector. In 2016-2017, the allocation was BDT. 16,217.83 crore for 88 projects. This is a significant funding increase and marks a substantial growth of 505.92 percent.<sup>17</sup>

Figure 4  
BANGLADESH: GDP GROWTH RATE TREND AND KEY EVENTS



Source: International Monetary Fund (IMF), *A Shifting Global Economic Landscape* (Washington D.C.: IMF, 2017).

Table 2  
 BANGLADESH: HISTORICAL NET ELECTRICITY GENERATION, 2000–2017  
 (in GWh—gigawatt-hours)

Fiscal Year	Net Electricity Generation (GWh)	Yearly Net Electricity Generation Growth Rate (%)	Remarks (increase/decrease over previous year)
2000–2001	16,255	10.29	(+)
2001–2002	17,445	7.32	(+)
2002–2003	18,458	5.81	(+)
2003–2004	20,302	9.99	(+)
2004–2005	21,408	5.45	(+)
2005–2006	22,978	7.33	(+)
2006–2007	23,268	1.26	(+)
2007–2008	24,946	7.21	(+)
2008–2009	26,533	6.36	(+)
2009–2010	29,247	10.23	(+)
2010–2011	31,355	7.21	(+)
2011–2012	35,118	12.00	(+)
2012–2013	38,229	8.86	(+)
2013–2014	42,195	10.37	(+)
2014–2015	45,836	8.63	(+)
2015–2016	52,193	13.87	(+)
2016–2017	57,276	9.74	(+)

Source: Power Development Board (PDB) *Annual Report, 2016–2017* and Bangladesh Power Development Board (BPDB), *On the Issue of Increase in Power Tariff* (Dhaka: BPDB, 2018).

**Industrial Production Growth Rate Trends in Bangladesh:** The government’s commitment to funding the power sector was prudent given the importance of electricity to fuel the country’s growth and, in particular, industrial production growth. Table 3 provides an overview of the industrial production growth rate and the reader can see the robust rates. The growth rate entries provide the annual percentage increase in industrial production, which includes manufacturing, mining,

Table 3  
 BANGLADESH: INDUSTRIAL PRODUCTION (IP) GROWTH RATE TREND, 2001–2017

Year	IP Growth Rate	Year	IP Growth Rate	Year	IP Growth Rate
2001	6.2%	2007	8.4%	2013	9.0%
2002	1.8%	2008	6.9%	2014	8.8%
2003	1.9%	2009	6.5%	2015	8.6%
2004	6.5%	2010	6.4%	2016	8.4%
2005	6.7%	2011	7.4%	2017	8.2%
2006	7.2%	2012	9.5%		

Source: Central Intelligence Agency (CIA), *World Fact Book*, (Washington, D.C.: CIA, 2017).

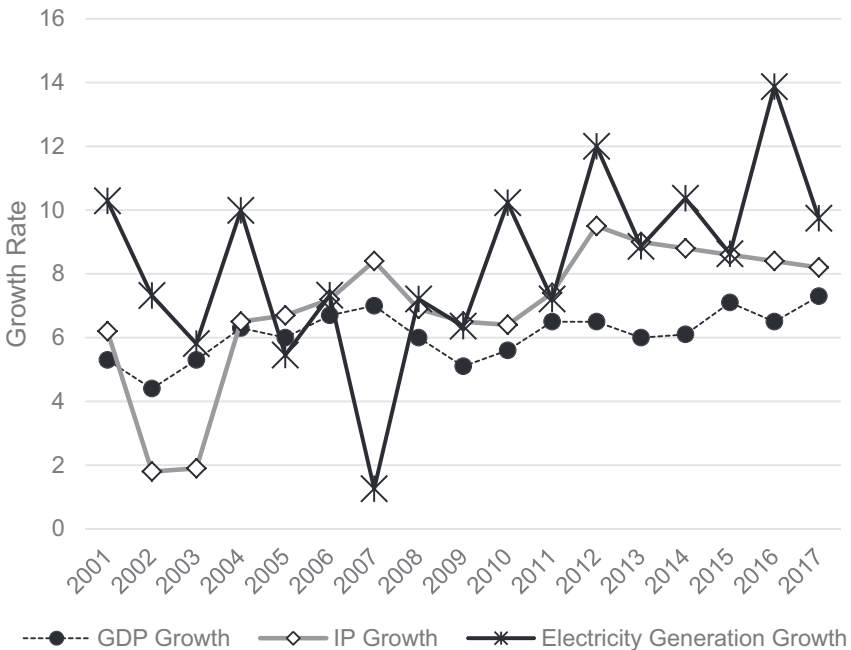
and construction. Further, the manufacturing industry includes large- and medium-sized electricity intensive industries.

From figure 5, we can see that the GDP growth trend was more or less stable from 2001 to 2017. However, the net electricity generation growth exhibited sizeable fluctuations and was unstable during the period under study sometimes approaching 10 percent and other times below 5 percent. The industrial production (IP) growth rate was unstable from 2001 to 2004 but was moderately stable from 2005 to 2017.

### *Methodology*

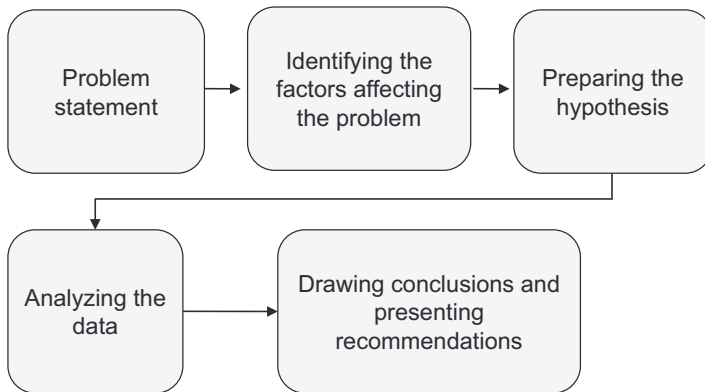
**Research Design, Data Collection, and Sampling:** To investigate the relationship among real GDP growth, net power generation growth, and industrial production growth (manufacturing, mining, and construction) for Bangladesh, the research design framework presented in figure 6 was utilized.

Figure 5  
BANGLADESH: GROWTH RATES OF GROSS DOMESTIC PRODUCT (GDP), INDUSTRIAL PRODUCTION (IP), AND NET ELECTRICITY GENERATION, 2001–2017  
(in percentages)



Source: Author's compilation.

Figure 6  
RESEARCH DESIGN STEPS



Source: Author’s compilation.

Based upon the design model presented in figure 6, the first two steps are outlining the problem statement and then identifying the factors contributing to that problem. This is followed by the preparation of the hypothesis, analyzing the data and results, and offering the conclusions from the research. For this study’s data collection, we had to construct the appropriate system of sampling and data collection procedure first. In this study we have collected 17 years as our sample size for GDP growth rate, net electricity generation, and the quantum index of medium- and large-scale electricity intensive manufacturing industry for Bangladesh.

We collected the data from various information sources including the Bangladesh Bureau of Statistics, International Energy Agency (IEA), World Economic Review, Bangladesh Energy Regulatory Commission (BERC), Power Division, and Bangladesh Power Development Board (BPDB) for the variables in our study and over our sample period.

**Hypothesis Development:** For our analysis of the GDP growth rate, we ran multiple regression models. Our variables were as follows:  $Y = \text{GPD growth rate}$ ,  $X1 = \text{industrial production (IP)}$ , and  $X2 = \text{net electricity generation (NG)}$ . The regression function,  $Y = f(X1, X2)$  and the regression equation is given as  $Y = B + B1*X1 + B2*X2$ .

This study intends to examine the relationship among the GDP growth rate, net electricity generation growth rate, and industrial production growth rate. The model has been set up as follows:

$$GDP\_Rate = f(Gene\_Gr, IP\_GR) \tag{1}$$

where *GDP\_Rate* = GDP growth rate, *Gene\_Gr* = net electricity generation growth rate, and *IP\_GR* = industrial production growth rate.

Empirical studies show that most of the time series are not stationary. Indeed, the visual inspection of all the variables intended to be used in this study in their levels suggests that they are trending and, therefore, non-stationary. That is, their mean and variances depend upon time. As econometric theory shows, when the variables are non-stationary, the standard ordinary least squares cannot be applied because there might be a spurious regression that affects forecasting performance. As a result, we used a time series regression model (as IP data was difficult to obtain prior to year 2001). As our data set involves a multivariate time series, the optimal method of regression analysis is the vector auto-regression (VAR) model or the vector error correction model (VECM). To undertake these analyses, we follow the outlined steps: (1) lag selection of the variables, (2) a stationarity check, (3) test for co-integration, and (4) if co-integration is not present, we will apply VAR and if co-integration is present, we will apply VECM.

### **Data Analysis**

**Lag Selection of Variables:** To select the optimal lag we set the maximum optimal lag 1 as our data set showed yearly data. To select the optimal lag, we used four parameters: the Final Prediction Error (FPE), Akaike Information Criterion (AIC), Hannan Quinn Information Parameters (HQIC), and Schwartz Information Parameters (SBIC). The results are presented in table 4 and the optimal lag is 1 (denoted by \*).

**Stationarity Check:** As stated earlier, time series data are normally non-stationary. However, to run a successful regression test for time series data we need to make them stationary because time series cannot have a constant mean and variance. The Dickey Fuller test helps to examine the stationarity in time series data. An important assumption of this test is that the error term is uncorrelated. Therefore, the Augmented Dickey Fuller (ADF) test was conducted in the study, wherein we checked the error term correlation by adding lags.

Table 4  
LAG SELECTION OF VARIABLES <sup>a</sup>

Lag	LL	LR	df	P	FPE	AIC	HQIC	SBIC
0	-13.939				0.429	1.992	1.991	2.039
1	-12.089	3.699	1	0.054	0.384*	1.879*	1.878*	1.973*
2	-11.568	1.042	1	0.307	0.411	1.943	1.941	2.084

<sup>a</sup> FPE = Final Prediction Error, AIC = Akaike Information Criterion, HQIC = Hannan Quinn Information Parameters, SBIC = Schwartz Information Parameters, and \* = optimal lag. Sample 2003–2017, number of observations = 15, endogenous *GDP\_Rate*, exogenous = *\_cons*.

Source: Author's calculations.

To test the stationarity of data we had the following hypothesis:  $H_0$ : the data is non-stationary and  $H_1$ : the data is not non-stationary. For decision making, we considered the 1-percent, 5-percent, or 10-percent significance levels in the analysis. When the absolute value of the test statistics is more than the critical value, we can reject the null hypothesis. But if the absolute value of the test statistics is less than the critical value, we cannot reject the null hypothesis.

The results of the Augmented Dickey-Fuller unit root test are presented in table 5. Here we saw that in case of GDP growth rate (GDP\_Rate), electricity growth rate (Gene\_Gr), and the industrial production growth rate (IP\_GR) at level data, the absolute value of the test statistics is more than the critical value. Thus, we rejected the null hypothesis that the data was non-stationary.

**Test for Co-integration:** If a series is non-stationary in a time series without a constant mean and constant variance, the regression results will be spurious. But regression results could be reliable when a linear combination of non-stationary series (dependent and independent) removes the stochastic trend and produces stationary residuals. Therefore, it is implied that variables are co-integrated. Co-integrated also assumes that there is the occurrence of stochastic non-stationary series, underlying two or more process. To test co-integration, the Johansen co-integration test is widely used. The test gives the rank of co-integration. The order of integration of a series is given by the number of times. The series must be differenced in order to produce a stationary series. A series generated by the first difference is integrated of order 1 denoted as I(1). Thus, if a time series is I(0), it is stationary; if it is I(1) then its change is stationary and its level is non-stationary. The Johansen co-integration test is based on the maximum likelihood method and gives two main statistics: the trace statistic and maximum statistic. When the rank is zero it means there is no co-integration relationship and if the rank is one it means there is one co-integration equation and so on. The null and alternative hypotheses are as follows:  $H_0$ : there is no co-integration and  $H_1$ : there is co-integration (table 6).

At maximum rank zero, the trace statistic is less than the critical value. Therefore, there is non-rejection of the null hypothesis, indicating the time series

Table 5  
RESULTS OF THE AUGMENTED DICKEY-FULLER TEST FOR UNIT ROOTS <sup>a</sup>

Variable	Level	1 <sup>st</sup> Difference
GDP_Rate	-3.361**	-3.815*
Gene_Gr	-2.169***	-3.882*
IP_GR	-3.597**	-5.447

<sup>a</sup> \* denotes the rejection of the null hypothesis at the 1-percent significance level; \*\* denotes the rejection of the null hypothesis at the 5-percent significance level; and \*\*\* denotes the rejection of the null hypothesis at the 10-percent significance level. GDP\_Rate = GDP growth rate, (Gene\_Gr) = electricity growth rate, and (IP\_GR) = the industrial production growth rate.

Table 6  
RESULTS OF THE JOHANSEN TESTS FOR CO-INTEGRATION <sup>a</sup>

Maximum Rank	Eigenvalue	Trace Statistics	Critical Value	Max Statistics	Critical Value
0	–	25.3773*	29.68	12.3557	20.97
1	0.53802	13.0216	15.41	9.7431	14.07
2	0.45608	3.2785	3.76	3.2785	3.76
3	0.18527				

<sup>a</sup> \* denotes the rejection of the null hypothesis at the 5-percent significance level.

variables GDP\_Rate, IP\_GR, and Gene\_Gr are not co-integrated. Similarly, the max statistic is less than the critical value, which indicates non-rejection of the null hypothesis. Thus, for the maximum rank zero, GDP\_Rate, IP\_GR, and Gene\_Gr are not co-integrated.

At maximum rank one, the trace statistic is less than the critical value. Therefore, there is non-rejection of the null hypothesis so the time series variables GDP\_Rate, IP\_GR, and Gene\_Gr are not co-integrated. Similarly, the max statistic is less than the critical value, thus, there is non-rejection of the null hypothesis. For the maximum rank one, GDP\_Rate, IP\_GR, and Gene\_Gr are not co-integrated.

At maximum rank two, the trace statistic is less than the critical value. Therefore, there is non-rejection of the null hypothesis indicating the time series variables GDP\_Rate, IP\_GR, and Gene\_Gr are not co-integrated. Similarly, the max statistic is less than the critical value meaning there is non-rejection of the null hypothesis. For maximum rank two, GDP\_Rate, IP\_GR, and Gene\_Gr are not co-integrated.

Since the results indicate there is non-co-integration between these variables, a vector auto regression model will be the appropriate model to apply. The resultant equation will be as follows:

$$\text{GDP\_Rate}_t = \alpha + \beta_1 \text{IP\_GR}_{t-1} + \beta_2 \text{Gene\_Gr}_{t-1} + \epsilon$$

**Vector Auto Regression (VAR):** Table 7 provides the results of the regression equations by taking “D\_GDP\_Rate” as dependent and lagged values of IP\_GR and Gene\_Gr as the independent variables. To ascertain the short-term causality between variables, the individual lag coefficients need to be negative with significant p values for each independent variable. As per this criterion we saw that the lagged value of IP\_GR has short-term causality with GDP\_Rate at the 10-percent significant level; as a result we accepted the null hypothesis. On the other hand, Gene\_Gr does not show any significant short-term relationship with GDP\_Rate, thus rejecting the rest of the null hypothesis.

Table 7  
VECTOR AUTO REGRESSION RESULTS <sup>a</sup>

Variable	Coefficient Interval	Standard Error	z	P>z	95% Confidence
D_GDP_rate	0.1927	0.2975	0.65	0.510	-0.3904
LD	0.7759				
IP_GR	-0.1915	0.1191	-1.61	0.098	-0.4249
LD	0.0420				
Gene_Gr	0.0189	0.0457	0.41	0.679	-0.0707
LD	0.1086				
_Cons	0.2015	0.1637	1.23	0.218	-0.1193
	0.5222				
	Parms	RMSE	R <sup>2</sup>	Chi <sup>2</sup>	P>chi <sup>2</sup>
D_GDP_rate	4	0.7338	0.1599	2.8543	0.4146
D_IP_GR	4	1.3134	0.3320	7.4564	0.0587
D_Gene_Gr	4	2.9447	0.5726	20.0994	0.0002

<sup>a</sup> Sample: years 2003–2017; number of observations = 15; log likelihood = -67.3321; Final Prediction Error (FPE) = 8.1957; Akaike Information Criterion (AIC) = 10.5776; Hannan Quinn Information Parameters (HQIC) = 10.5716; Schwartz Information Parameters (SBIC) = 11.1441; Det (Sigma\_ml) = 1.5904. GDP\_Rate = GDP growth rate, (Gene\_Gr) = electricity growth rate, (IP\_GR) = the industrial production growth rate, LD = lagged value, Parms = parameters, RMSE = root mean squared error, and z = raw score in terms of its distance from the mean.

### Findings & Recommendations

With Bangladesh poised to become one of the largest economies in Asia and playing a larger role in the global economy, understanding the linkages between the growth rates of GDP, electricity generation, and industrial production is critical. Furthermore, as the global community tackles the issue of climate change and how best to adapt economic development strategies to have a lower-carbon footprint, the issue of understanding how best to implement sustainability and energy security policies and strategies becomes even more important. Moreover, Bangladesh has been identified as one of the nations most vulnerable to the threats from climate change due to its geographic location and rising sea levels along with the intensification of climate-change induced natural disasters. Thus, this work is important in that it adds to the literature by analyzing the relationship between industrial production growth, net electricity generation growth, and GDP growth for Bangladesh using a time series analysis, such that it can help frame the discussion for policy makers, researchers, and academics.

Using annual data covering 17 years, the results obtained from the paper suggest that in the short run there is a significant relationship between the GDP growth rate and the industrial production growth rate in Bangladesh. Moreover, the paper also found that there is a significant increase in net electricity generation (see table 2),

which is an encouraging sign for starting toward the path of energy security. This generation is influencing the industrial production growth in Bangladesh. Bangladesh has had a moderately stable GDP growth rate for last decade. However, consumers will only enjoy the full benefits of energy when both the quality and the availability of energy in the system can be safeguarded. In order to ensure the nation's energy security and GDP growth, the following recommendations are being offered: (1) the country needs to maximize the use of renewable energy sources; (2) the country must look toward investing in and developing cleaner energy solutions; (3) the country needs to develop its power market; (4) cost reflective tariffs need to be implemented; (5) energy efficiency should be prioritized; (6) capacity building should be expanded; and (7) further investment in grid stability is needed.

The optimal energy mix will vary from country to country; however, diversification of fuel from different sources is essential in all cases. Bangladesh must prioritize its energy security and since the country cannot rely on only one source to meet its large and growing demand, a diversification of energy sources is necessary for energy security and for a sustainable future.

#### NOTES

<sup>1</sup>International Energy Agency (IEA), *On the Issue of Energy Efficiency Market* (Paris: IEA, 2014).

<sup>2</sup>World Energy Council (WEC), *On the Issue of World Energy Monitor* (London: WEC, 2014).

<sup>3</sup>J. Dernbach, "Can the Battle Against Climate Change Become an Effective Social Movement," *Ethics in Science and Environmental Politics*, vol. 11, no. 1 (2011), pp. 27–30.

<sup>4</sup>M. Munus, B. Moingeon, and L. Lehmann-Ortega, "Building Social Business Models: Lessons from the Grameen Experience," *Long Range Planning*, vol. 43 (2010), pp. 308–25.

<sup>5</sup>A. Šimelytė and G. Dudzevičiūtė, "Consumption of Renewable Energy and Economic Growth," in *Modern Business Management Problems and Perspectives* (2017), available at <https://doi.org/10.3846/cbme.2017.048>.

<sup>6</sup>M. Bortolini, M. Gamberi, and A. Graziani, "Technical and Economic Design of Photovoltaic and Battery Energy Storage System," *Energy Conversion and Management*, vol. 86 (2014), pp. 81–92.

<sup>7</sup>S. H. Schurr, "Productivity Efficiency and Energy Use: An Historical Prospective," *Annals of Operation Research*, vol. 2 (1984), pp. 229–38.

<sup>8</sup>Ibid.

<sup>9</sup>D. Barnes and W. M. Floor, "Rural Energy in Developing Countries: A Challenge for Economic Development," *Annual Review of Energy and Environment*, vol. 21 (1996), pp. 497–530.

<sup>10</sup>R. J. Barro and X. Sala-i-Martin, *Economic Growth* (Cambridge: Cambridge MIT Press, 1995), pp. 455–68.

<sup>11</sup>Bangladesh, General Economics Division, Ministry of Planning (MOP), *6th Five-Year Plan* (Dhaka: MOP, 2014).

<sup>12</sup>Bangladesh, Power Division, Ministry of Power, Energy and Mineral Resources (MPEMRD), *Annual Report of Power Division 2017–2018* (Dhaka: MPEMRD, 2018).

<sup>13</sup>Ibid.

<sup>14</sup>Ibid.

<sup>15</sup>Bangladesh, Energy Regulatory Commission (BERC), *Annual Report 2017–2018* (Dhaka: BERC, 2018).

<sup>16</sup>International Energy Agency (IEA), *On the Issue of Energy Efficiency in China* (Paris: IEA, 2016).

<sup>17</sup>Bangladesh Power Development Board (BPDB), *On the Issue of Increase in Power Tariff* (Dhaka: BPDB, 2018).