Energy Diversification : The Only Alternative to Ensure Energy Security in Bangladesh

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[Abstract : The aims of this paper are to examine the power and energy supply scenarios, identify the key factors of the energy crisis, and examine whether energy diversification should be treated as only one solution or not to overcome the power crisis in Bangladesh. Qualitative and Quantitative research approaches have been designed to collect and analyze the data. The study reveals that the primary energy sources are not secured. More revealing is that population density, private sector investment, primary energy depletion, composition of energy, industry structure, and energy prices stimulate the energy crisis. Fuel (Primary Energy) diversification has been suggested as the only recommended solution where efficient management, technological advancement, and private sector investment are requisite to implement a diversification strategy properly.]

Key Words : Power and Energy, Energy Crisis, Energy Security, Diversification, Sustainability.

Introduction

Energy is essential for the economic growth of a country (Ayres and Warr, 2010; Quinn, 2014). Different forms of energy are light energy, heat energy, mechanical energy, gravitational energy, electrical energy, sound energy, chemical energy, nuclear or atomic energy, and so on (Salehabadi et al., 2020). The sources of energy have been categorized into renewable energy (i.e., solar energy, geothermal energy, wind energy, biomass from plants, hydropower from flowing water, etc.) and non-renewable sources (i.e., oil, coal, and natural gas, etc.) (Elavarasan, 2019; Spanish Institute of Strategic Studies, 2014). Non-renewable sources are finite and are going to replenish someday (Hossain, 2012).

The world economy is now facing challenges from an interrupted energy supply and climate change (Rony, 2019). The world economy has grown fast in the last few decades, and GDP growth is mainly dependent on the sustainability of power and energy (Asif and Muneer, 2007). Energy sustainability is not ensured due to the dependence on fossil fuels (Awan and Khan, 2014). A study shows that fossil fuel production, i.e., oil, natural gas, and coal production, will diminish within the next few decades (Asia Pacific Energy Research Centre, 2007). Along with these, the world is now facing environmental degradation from fossil fuel usage.

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Different environmentalists urge the issue of clean energy consumption, recommending non-fossil fuels over fossil fuels. Different developed countries, like the Netherlands, Denmark, Japan, Germany, etc., are strongly obedient on these issues (Robert and Ichord, 2020).

Bangladesh, a highly vulnerable country, is now experiencing the impact of climate change (Hutfilter et al., 2019). The projection of GDP loss is 2% by 2050 and 9.4% by 2100 due to environmental issues (De Colombia, 2015). According to the 7th five-year plan of the People's Republic of Bangladesh, the energy supply shortage is the barrier to overall economic growth (General Economic Division, 2015). This gap leads to a one-billion-dollar loss in industrial output (Mahajan et al., 2014). Though the per capita consumption (kWh) increases each year (375 kWh in FY2019 and 378 kWh in FY2020), the peak generation of electricity has reduced from 12,893MW to 12,738MW. On the other hand, peak demand shifted from 12,100MW to 13,300MW (Bangladesh Power Development Board, 2020). According to the projection of the Renewable Energy Policy in 2008, the target has been set to generate power from renewable sources of 5% by 2015 and 10% by 2020 (Pargal, 2017). But the current scenario is disappointing. Only 0.07% of power is generated from renewable energy sources. The situation is also deteriorating due to increased dependence on fossil fuels and improper policy implications. Natural gas is still the dominant fuel for power generation in 2020. Natural gas dependence for power generation increased as it was 71.82% in 2020 and 68.49% in 2019 (Bangladesh Power Development Board, 2020)

Natural gas reserves are now in a frightening situation as their demand upsurges by 7.5% each year (Kabir and Uddin, 2015). According to the study by Japan's International Cooperation Agency (JICA) on International Energy Agency (IEA) country statistics in 2015, Bangladesh's natural gas reserves will last until 2031 if the consumption pattern of natural gas in energy generation is continued at the current rate (Murshed and Amin, 2018; Ministry of Power, Energy and Mineral Resources, 2016). According to the Annual Report of Petrobangla (2019), the highest portion of natural gas is consumed by the power sector, which is 43.28%. According to the statistical data, cumulative production was 16769.45Bcf and the remaining reserve was 9490.34Bcf till the end of FY2019. Gas demand is expected to be 3955Bcf in 2020, 4178Bcf in 2021, 4752Bcf in 2022, 4957Bcf in 2023, 5335Bcf in 2024, and 5243Bcf in 2025.

So, these issues require research on power and energy sectors to overcome the upcoming, inevitable crisis of energy in Bangladesh. The purposes of the study are to examine the current scenario of the power and energy sectors, identify the stimulators of the energy crisis and find out whether energy diversification is the only alternative or not to secure energy in Bangladesh.

Literature

Theoretical Framework

The World Bank (2017) assessed the operational management of power and energy sectors in Bangladesh from 2014 to 2017. Study results showed that the country was suffering from an acute power supply shortage and was urged to concentrate on importing LNG. The key challenges of the power sector in Bangladesh have been identified, i.e., risk to fuel supply steadily, demand supply gap, and more dependence on natural gas for power generation. It also assessed the realism of government policy to overcome the challenges. The recommendation has also been given to universal access to power, i.e., developing a market for cross-border imports, moving toward clean energy, and utilizing the maximum potential of renewable energy sources. Islam and Khan (2017) also examined the current and future scenarios of the power and energy sectors and highlighted the energy mix. A study found that the energy sector is facing challenges like the increasing demand for electricity, the electricity-uncoverage age of a large population, extreme load shedding, and the low voltage of power supply. Fuel diversification, dependence on renewable energy, energy efficiency and conservation are recommended to overcome these challenges.

The power sector scenario has been reviewed by Haque (2020), who presents the power scenario at a glance, installed power capacity, fuel mix for power generation, tariff structure, explores the opportunity of the private sector and long-term projects of the government of Bangladesh. The scenario of electricity supply is suffering from a supply shortage, and it was acute during peak time. Though the government has taken different projects on coal, liquefied natural gas, and nuclear power plans, which deems the light a little bit.

Mujeri et al. (2014) have conducted a study on the review of the energy sector in Bangladesh and its reform. The study has discussed the trends in petroleum and electricity subsidies, pricing policies, and the government's agenda for sector development. The Bangladesh Energy Regulatory Commission (BERC) fixes the price, which is lower than the market price. And the additional part is filled up by subsidies. Subsidies are increasing as the market price rises day by day.The study also reveals that the demand-supply gap is increasing but the primary fuel supply is contracted. Concern should be given to the maintenance of the installed power plant and Demand Side Management (DSM).

The Asian Development Bank (2019) has run a program on sector assessment of the power sector in Bangladesh. Some indicators, i.e., relevance, effectiveness, efficiency, and sustainability, are used to assess the performance of the power sector. Natural gas is the dominant fuel for electricity generation. Natural gas is not able to meet the increasing demand. The minimal price of natural gas makes the policy unsustainable. So, the diversification from natural gas to renewable sources,

demand-supply energy efficiency, a suitable environment for private investment, and regional cooperation is highly recommended. According to Pargal (2017), the power supply shortage is 30%. 10% of industries remain idle due to the power crisis. The recommendation has been given to emphasis on the development of local solar panels, the issue of soft loans for renewable energy and tariff adjustment to encourage private sector investment in the power sector.

A study has been conducted on the present scenario of power and the sector by Khairul and Husnain (2011). A study reveals that the country faces an acute power crisis. The reasons for this crisis are the limited resources, low production capability, high demand, and old machineries for power generation. This paper recommends maximizing the utilization of renewable energy. The geographic location of our country is favorable for renewable energy sources, i.e., an ideal location for photovoltaic energy, micro hydro for riverine country, and wind energy potential for hilly and coastal areas.

Haque and Rahman (2010) in their study identified the electricity crisis, misuse of existing installed capacity, system loss, and mismanagement in the power sector. More dependence on natural gas makes the situation miserable. This paper reviews the government's renewable energy program and recommends expanding it later. Another study has been conducted on the energy crisis by Bagdadee and Islam (2015). The study reveals that conventional fuel pressure is increasing due to the reliance on natural gas and oil for power generation. This stimulates the price and creates an imbalance. Technological advancement to replace fossil fuels with renewable energy and investment in doing research should be strongly emphasized.

Many studies have been conducted on the prospect of geothermal energy, solar energy, wind energy, and wave energy. Coal and natural gas emit carbon. Das (2017) recommends the proper utilization of geothermal energy. Geo means earth and thermal means heat. The paper explores prospective sites in the north-west region. Bangladesh can follow the neighboring country's effort (India) for regional similarity. According to Kowsar et al. (2010), solar energy is the only solution to the energy crisis in Bangladesh. This country has a huge scope for renewable energy. Multi-junction tandem solar cells are highly recommended for efficient use of solar energy.

The problems, i.e., shortage of natural gas, unreliable old energy plants, and increasing demand, have been identified by Saifullah et al. (2016). Bangladesh has enormous potential, with a projected 1250 GWh generation from wind resources.Bangladesh is an agricultural country. Wind energy takes small space and continues with existing agricultural land. Rony (2019) in his study reveals the wave energy potential in Bangladesh. The most suitable for wave energy are Cox's Bazar, Moheskhali Island, Kutubdia Island, Sandwip Island, and the Hiron point in Bangladesh.

According to Pellerin-Carlin et al. (2017), the transformation of non-renewable energy into renewable energy is needed. The European Union has signed a deal for clean energy. A study has been conducted by Robert and Ichord (2020) on the transformation of non-renewable to renewable energy. GDP growth demands additional energy. This study explores key challenges, i.e., energy deficiency, transparency, affordability, accessibility, environmental sustainability, and financial viability. The statistical report shows that solar access rose from 9% in 2016 to 14% in 2018. The World Bank estimates 11.2 billion USD in 2016 losses due to weak management in the power sector.

The Asia Pacific Energy Research Centre (2007) urges the importance of energy security. This study details the world's energy history. Oil production is falling all over the world. It forecasts fossil fuels will diminish within a few decades. The performance of world energy has been evaluated by using a few key performance indicators, i.e., availability, accessibility, acceptability, and cost competitiveness. Oil prices are increasing each year by 1.7%, and the price also increases. In contrast, supply decreases from 56% to 47%. So, the demand has shifted to natural gas in recent years. But the reserve will end up lasting 80 years. Coal is cheap and affordable, but it emits carbon. Nuclear power plants are gaining popularity, but uranium will only be available in the twenty-first century.

An assessment has been conducted on the energy sector in Bangladesh by Uddin et al. (2016). Seven indicators, i.e., resource availability, balance, demand, expenditure, environmental concern, technological advancement, and energy sector investment, are considered. Energy is not secured as a primary resource due to unavailability, imbalance between renewable and non-renewable energy sources, unfulfilled energy demand, fluctuating energy prices, technological backwardness, and limited budget for sector development.

Many studies have been conducted on the current scenario of power and energy demand and supply, the challenges of the power and energy sector, and recommended solutions in the context of Bangladesh. But the studies fail to give a broad overview of the power and sector, how the stimulating factors are liable to aggravate the energy crisis and the degree of accountability of those factors, and even indirectly recommend the diversification strategy as a solution to meet the crisis. Many solutions have been given but do not give an argument which one fits more in Bangladesh to meet SGD 7. This paper is designed to meet these gaps.

Conceptual Framework

Different variables have been identified that stimulate the energy crisis badly. A model based on the literature is drawn below-

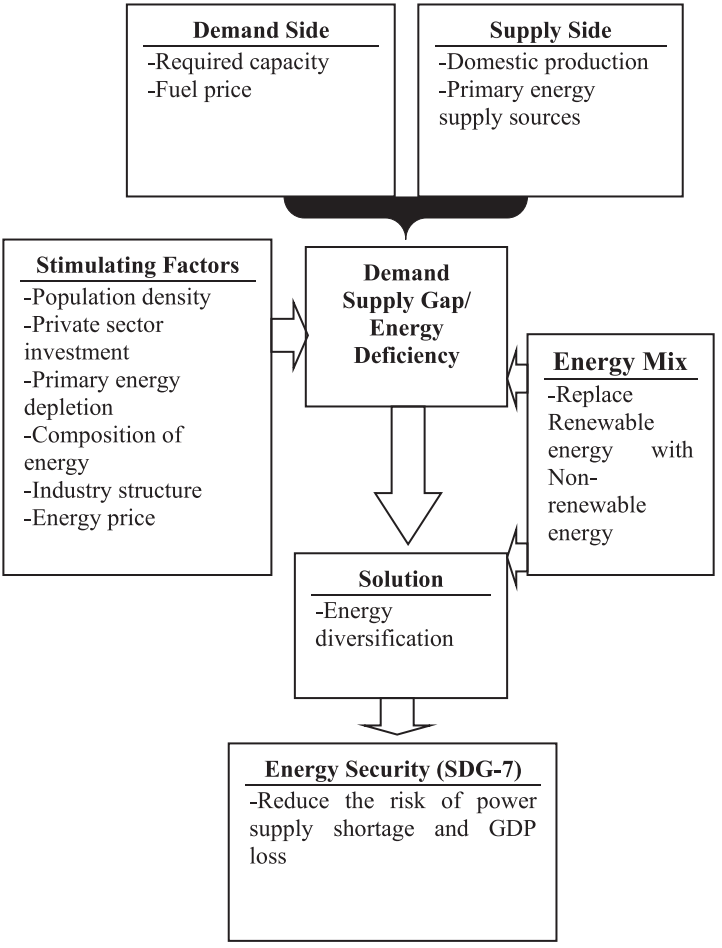


Figure 1 : Conceptual framework.

Source : Petrobangla, 2019; Ministry of Power, Energy and Mineral Resources, 2016; Bangladesh Power Development Board, 2019; BIPPA, 2018; Rahman, 2020; Uddin, Ahmed, &Ahmmed, 2016.

Hypothesis

In this study, the null hypotheses (H0) and alternative hypotheses (H1) have been developed to understand the current scenario of the energy sector and identify the stimulating factors. These are listed below in the table.

Table 1 : Proposed hypotheses.

Hypothesis : 1	H0 : Primary energy sources are not secured. H1 : Primary energy sources are secured.
Hypothesis : 2	H0 : Population density, private sector investment, primary energy depletion, composition of energy, industry structure, and energy price have significant effect on the demand supply gap. H1 : Population density, private sector investment, primary energy depletion, composition of energy, industry structure, and energy price have no significant effect on the demand supply gap.

Methodology

In order to fulfill the objectives of this research paper, a mix of qualitative and quantitative research design has been used. A qualitative research method has been used to assess the present scenario of the power and energy sectors and recommend solutions. Alongside, quantitative research methods have been used to test the hypothesis of whether the identified factors, i.e., population density, energy price, industry structure, private sector investment, primary energy depletion, and composition of energy, stimulate energy deficiency or not. It has collected data from both primary and secondary sources. A structured questionnaire [1]-based interview has been conducted to collect primary data using a random sampling technique [2]. The questionnaire has been divided into two sections, i.e., the open-mind answer section and a 5 point Likert scale (1 to 5) to measure the responses. Companies in Dhaka city have been visited to conduct interviews, and outside Dhaka city, interviews have been conducted via phone call and email. Journals, articles, reports, and well-reputed online newspapers have been accessed as secondary sources of data. The target population is constituted by the employees at managerial level (experts in the relevant fields, i.e., employees of the research department, director of planning committee, engineer in renewable energy section, project manager, assistant manager in planning and distribution cell, and site manager) in Power & Energy Company in Bangladesh. The total population is the expertise of the power and energy companies in Bangladesh. The company's location has not been given priority, but rather given emphasis on the nature of delivered products. The company has been randomly picked up from the power

sector, nuclear power plant, LPG, LNG supplier, coal and natural gas fields based on convenience. The respondents are two experts from each company, such as Petrobangla, Bangladesh Power Development Board (BPDB), Bibiyana Gas Field, Rooppur Nuclear Power Plant, Dhaka Electric Supply Company Limited (DESCO), Index Group, S. Alam Group, Orion Group, Boshundhara Group, and North-West Power Generation Company Ltd. (NWPGCL).

IBM SPSS Statistics 26.0 has been used to analyze and present the collected data. The independent variables of the study include population density, energy price, industry structure, private sector investment, primary energy depletion, and the composition of energy. The dependent variable is energy deficiency. Different measurement variables are shown in the table with statistical tools and indicators.

[1] A questionnaire that has a particular set of predefined questions is called a structured questionnaire (Gupta &Lehal, 2009)**.**

[2] Random sampling is an unbiased representation of the total population where each sample has been chosen at random (Sharma, 2017).

Table 2 : Measurement of variables.

Independent Variables	**Indicators**	**Scale**	**Data Analytical Tools**
Energy deficiency/ Demand supply gap of energy	-Production incapacity -Unable to meet demand -Unsecured primary energy supply sources	Ordinal/ Categoric al	Questionnaire/ Simple Linear Regression, Correlation and F test (ANOVA)
Dependent Variables			
Population density	Demand and consumption increase	Ordinal/ Categori cal	Questionnaire/ Simple Linear Regression, Correlation and F test (ANOVA)
Energy price	Unaffordability and efficient usage		
Industry structure	Usage efficiency and variance		
Private sector investment	New sources exploration and technological advancement		
Primary energy depletion	Limited reserve and unavailability		
Composition of energy	Variation of production capacity among the primary energy sources		

Operational Definition

Energy Crisis

An energy crisis, a society-wide economic problem, refers to the deficiency or imbalance of demand and supply (Kolodko, 2014). The Asian Development Bank (ADB) defines an energy crisis as a shortfall or restriction in the supply of natural energy resources (Poudyal et al., 2019).Significant bottlenecks in the energy resource supply can be defined as an energy crisis (Bielecki, 2002). Disruption and its unstable flow of natural energy resource supply are also treated as an energy crisis (Asia Pacific Energy Research Centre, 2007). In this paper, the energy crisis refers to the energy unaffordability, inaccessibility, and unavailability of fossil fuels, i.e., oil, coal, natural gas, etc.

Energy Diversification

Energy diversification means using different energy sources, suppliers and transportation routes to reduce dependence on a single resource or provider for energy supply (Vivoda, 2009). Energy diversification is a strategy deployed to bolster both economic and physical security and can mean depending on both renewable and non-renewable energy sources as well as multiple carriers of energy supply (Bioenergy, 2009). A country that diversifies its energy supply mix insulates itself from energy disruptions or deficiencies and strengthens its future energy security (Mankoff, 2009).In this paper, energy diversification means using multiple fuel sources (a mixture of renewable and nonrenewable sources) to generate power rather than depending on only one source.

Energy Security

Energy security is simply defined as the uninterrupted supply of energy from available sources at a reasonable price with an even continuous distribution flow of energy (Winzer, 2012). Energy security refers to the availability of energy supply sustainably and timely, with affordable payment in an economy. The key features of energy security are availability, affordability, accessibility, fuel and supplier diversification, and environmental sustainability (Asia Pacific Energy Research Centre, 2007; Kruyt et al., 2009). In this study, energy supply will be secured when primary energy supply is available, affordable, and accessible.

Power and Energy Sector Scenario in Bangladesh

Day by day, power demand exceeds supply in Bangladesh. At present, almost 97% of the population is under electricity coverage till 2019. The maximum power demand in 2019 was forecasted at 13,300MW, while the demand was met at 12,738MW. It is a good sign that per capita power generation and consumption are increasing over the year. Domestic power consumption is higher than it was at the end of 2019, accounting for approximately 57.02% of total power consumption.The

other users are 27.58% industrial, 10.19% commercial, 2.42% agriculture, and 2.79% multi-purpose. Usage over the decades has increased in these sectors. From 2010 to 2019, the usage amount has moved upward domestically from 16,21,596 to 27,496,620, where total usage jumped from 20,67,338 to 32,36,886. The use of natural gas is increasing over the years, but its reserves are diminishing. ([1]

Though the country has experienced tremendous success in the power sector, unfortunately, it has failed to utilize the installed capacity due to age, lack of technological implications, and obsolete equipment in most of the power units in the public sector. Out of a total installed capacity of 20,383 MW in 2019, public, joint venture, private and importers possess 9,717 MW (48%), 622 MW (3%), 8,884MW (43%) (7,332 MW IPP/SIPP, 1,301 MW Rental Power Plant, 251 MW under REB) and 1,160 MW (6%). The maximum peak generation was 12,738 MW, which was 1.20% lower than that in the previous year. Total net energy generation was 71,419 GWh in 2019, which includes the public sector at 35,316 GWh, the private sector at 29,429 GWh (including REB), and 6,674 GWh of imported energy. It is 1.26% higher than the previous year's net generation (70,533 GWh). Net energy generation in the public sector was 35,316 GWh and 29,429 GWh in the private sector (including REB). Among the total installed capacity (20,383MW), the installed capacity is 230MW (1.13%) from hydro, 10,979MW (53.86%) from gas, 5,540MW (27.18%) from furnace oil, 1,290MW (6.33%) from diesel, 1,146MW (5.62%) from coal, 38MW (0.19%) from solar PV and 1,160MW (5.69%) from power imports. Among the total power generation (71,419GWh), the generation is 825GWh (1.16%) from hydro, 51,290GWh (71.82%) from gas, 9,416GWh (13.25%) from furnace oil, 139GWh (0.20%) from diesel, 2,968GWh (4.16%) from coal, 62GWh (0.19%) from solar PV, and 6,674GWh (5.69%) from power imports. [2]

More dependence on indigenous natural gas poses a threat to meeting upcoming demand in the power sector. The statistical data in 2015 shows that the natural gas reserves will last until 2031, as per the opinion of the International Energy Agency (IEA) (Murshed and Amin, 2018; Ministry of Power, Energy and Mineral Resources, 2016). In FY 2019-2020, cumulative production was 16769.45Bcf and the reserve remained at 9490.34Bcf. The gas demand is forecasted to be 395Bcf by 2020, 4178Bcf by 2021, 4752Bcf by 2022, 4957Bcf by 2023, 5335Bcf by 2024, and 5243Bcf by 2025 (Petrobangla, 2020).

Fuel prices have also risen in recent decades. In 2010, the price of diesel oil (TK/Lit), furnace oil (TK/Lit), natural gas (TK/1000Cft) and coal (US $/M. Ton) was 42.71 TK, 26TK, 79.82TK, and 86$. The fuel price at the end of 2019 was per unit diesel at 65TK, furnace oil at 42TK, natural gas at 126 and coal at 130 USD (Bangladesh Power Development Board, 2020).

The government of the People's Republic of Bangladesh has made aggressive plans

to mitigate the energy deficit. According to the Power Supply Master Plan 2016 (PSMP), the capacity requirement is 30,000 MW in 2030 by using 35% coal and 35% LNG/Gas. Around 43 power generation projects with a capacity of 15,294 MW are under construction now, and the plan also envisions around 21,977 MW of new generation by 2025. This plan emphasizes a mixture of fuels, which includes coal, power imports, limited usage of natural gas, nuclear power plants, LNG, and renewable sources (hydro, solar, wind, wave etc.). In order to ensure affordable, reliable, and environmentally friendly energy, renewable energy resources have been given priority. Till 2019, the government has taken the initiative on renewable energy-based projects, i.e., rooftop solar projects, solar PV projects, wind power projects, and solid waste-based power projects (Bangladesh Power Development Board, 2020; Petrobangla, 2020).

[1] Based on the Bangladesh Power Development Board's Annual Report for 2020, Petrobangla's Annual Report for 2020, and the Bangladesh Bureau of Statistics' Annual Report for 2020.

[2] Adapted from the Bangladesh Power Development Board's Annual Report for 2020; Bangladesh Bureau of Statistics, 2020.

Mean	4.0500
Std. Deviation	0.51042
Variance	0.261

Table 3 : Statistics

From interviewed data, affordability, availability, and reliability is justified. The experts disagree with the statements (Mean value 4.0500 in between 3.41 to 4.20)[2]that the primary sources are under budgetary limit, available, and reliable.

Once more, it is inquired directly in regards to their primary energy sources are ensuring energy security or not. 80% of the respondents agree that their primary energy sources are not secured. So, the null hypothesis is accepted.

*Range : Strongly Agree= 1 to 1.80, Agree = 1.81 to 2.60, Undecided = 2.61 to 3.4, Disagree= 3.41 to 4.20, Strongly Disagree= 4.21 to 5

Figure 2 :
Response rate of primary energy security.



Table 4 : Response rate of primary energy security.

	Frequency	Percent	Valid Percent
No	16	80%	80%
Yes	4	20%	20%
Total	20	100.0	100.0

As a result, the current state of the power and energy sectors is dire. And the interviewed data also indicates that the energy is not secured. This creates a barrier to obtaining Sustainable Development Goals (SDG). The increased dependency on natural gas and technological backwardness make this situation horrible. Along with these two, there are other stimulators which have been identified in the next section. The degree of accountability of each factor, as per the opinion of the experts, has also been described.

Key Factors of Energy Crisis in Bangladesh

Regression Analysis

In this paper, the multiple regression analysis model has been used to test the hypothesis. The likert data reflects that which is ordinal in nature; it has been converted into scale by using the mean transform value of identified variables. Two types of datasets prevail, such as parametric and nonparametric datasets. A test of normality has been used to determine the nature of a dataset, whether it is normally distributed or not. SKewness and Kurtosis, along with the Shapiro-Wilk model, have been used to determine whether the data is statistically significant or not. Skewness and Kurtosis values are divided by the standard error, which is in the range of +1.96 to -1.96 in the case of all variables. Alongside, the Shapiro-Wilk test also shows that the data is not statistically significant (sig. greater than 0.05). So, the dataset in both cases proves normally distributed and multi-linear regression is the best method to analyze study data.

Table 5 : Tests of Normality

			Shapiro-Wilk		
	Skewness/Std. Error	Kurtosis/Std. Error	Statistic	df	Sig.
Energy Deficiency	0.0313	-0.1815	0.925	20	0.122
Population Density	-0.502		0.866	20	0.100
Private sector investment	-0.001	0.1291	0.914	20	0.076
Primary Energy Depletion	0.420	-0.1109	0.855	20	0.060
Composition of Energy	0.0957	1.1181	0.931	20	0.162
Industry Structure	-0.5508	-0.4456	0.917	20	0.088
Energy Prices	-0.7344	-0.3953	0.907	20	0.057
a. Lilliefors Significance Correction					

The regression model summary shows that the value of R is 0.590, which indicates a high degree of correlation among the identified variables in this study. On the other hand, the R^2 value of 0.348 indicates that 34.8% percent of the variation in independent variables for energy deficiency is explained by the independent variables such as population density, energy price, industry structure, private sector investment, primary energy depletion, and composition of energy.

Table 6 : Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.590[a]	0.348	0.047	0.25382
a. Predictors : (Constant), Energy Prices, Primary Energy Depletion, Population Density, Industry Structure, Composition of Energy, Private sector investment b. Dependent Variable : Energy Deficiency				

The ANOVA table recommends that the regression model does not predict the dependent variable by the identified independent variables in this study significantly. As the p value (Sig. = 0.386) is greater than 0.05, it shows the statistical significance of the analytical regression model in this study.

Table 7 : ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	0.447	6	0.074	1.156	0.386[b]
	Residual	0.838	13	0.064		
	Total	1.284	19			

a. Dependent Variable : Energy Deficiency
b. Predictors : (Constant), Energy Prices, Primary Energy Depletion, Population Density, Industry Structure, Composition of Energy, Private Sector investment

The regression coefficients show that the independent variables such as population density, energy price, industry structure, private sector investment, primary energy depletion, and composition of energy have a significant impact on the energy deficiency or demand supply gap at a 0.05 level of confidence. As the sig. value in all variables is greater than 0.05, the null hypothesis has been accepted. The stimulating factors of energy deficiency are population density, energy price, industry structure, private sector investment, primary energy depletion, and energy composition.

Table 8 : Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.065	2.007		1.029	0.322
	Population Density	0.243	0.205	0.294	1.183	0.258
	Private sector investment	0.006	0.149	0.011	0.040	0.969
	Primary Energy Depletion	0.022	0.262	0.022	0.085	0.934
	Composition of Energy	0.158	0.109	0.380	1.442	0.173
	Industry Structure	0.015	0.191	0.021	0.081	0.937
	Energy Prices	0.124	0.155	0.195	0.799	0.438

a. Dependent Variable : Energy Deficiency

Pearson's Correlation Matrix

The Pearson correlation coefficient between the demand-supply gap and population density is computed as 0.340. It shows that there is a positive relationship between the two variables, with a significant level of 0.071 (0.01 Sig.). That means population density stimulates demand for supply gaps and enhances energy deficiency. In the case of private sector investment and energy deficiency, technology is closely related to the investment that stimulates the creation of new sources of energy. As it creates new sources, it indirectly helps to reduce energy deficiency. The Pearson Correlation coefficient of the lack of technology and demand supply gap is calculated as 0.147, which indicates a positive relationship with a significance level of 0.269 (0.01 Sig.).

The Pearson correlation coefficient of the primary energy depletion and demand supply gap is computed as 0.043. It implies that there is a positive relationship with the significant level of 0.428 (0.01 Sig.). On the other hand, the Pearson Correlation coefficient of the composition of the energy and demand supply gap is established at 0.447. It indicates a positive relationship where the significance level of these variables is 0.024 (0.01 Sig.). Industry structure and energy deficiency are positively related because if the industry is more nonrenewable energy intensive, these resources may last someday. The computed value of the Pearson Correlation coefficient is 0.282, which indicates the positive relationship among these variables with a significance level of 0.114 (0.01 Sig.). To determine the relationship between energy prices and energy deficiency, the Pearson Correlation coefficient is calculated at 0.374. So, energy prices and energy deficiency are correlated with a significance level of 0.052 (0.01 Sig.).

So, private sector investment, primary energy depletion, and industrial structure are correlated at a low level where the population density, composition of energy, and energy price are moderately correlated with the energy deficiency. [1]

[1] Correlation at three levels: low (0.01 to 0.33), moderate (0.34 to 0.64), and high (0.65 to 1.00)

Table 9 : Pearson's Correlation Matrix.

		Demand supply Gap	Population density	Private sector investment	Primary Energy depletion	Composition of energy	Industry Structure intensive	Energy price
Demand supply Gap	Correlation	1						
	Sig. (2-tailed)							
Population density	Correlation	**0.340**	1					
	Sig. (2-tailed)	**0.071**						
Private sector investment	Correlation	**0.147**	0.076	1				
	Sig. (2-tailed)	**0.269**	0.207					
Primary Energy depletion	Correlation	**0.043**	0.077	-0.458	1			
	Sig. (2-tailed)	**0.428**	0.373	0.021				
Composition of energy	Correlation	**0.447**	0.006	-0.035	-0.044	1		
	Sig. (2-tailed)	**0.024**	0.490	0.441	0.427			
Industry Structure intensive	Correlation	**0.282**	0.155	0.102	-0.129	0.468	1	
	Sig. (2-tailed)	**0.114**	0.257	0.334	0.294	0.019		
Energy price	Correlation	**0.374**	0.220	-0.199	0.122	0.288	0.200	1
	Sig. (2-tailed)	**0.052**	0.175	0.200	0.305	0.109	0.200	

Energy Diversification to Ensure Energy Security in Bangladesh

The statistical data indicates that the country is now facing a severe demand-supply gap. Due to a shortage of fuel supply, the power plant is not able to utilize its maximum capacity. The respondents agree that the primary energy sources are not secured. Population density, private sector investment, primary energy depletion, energy composition, industry structure, and energy price have all been identified as stimulators. When the respondents are asked about the suggested strategy to overcome the challenge, Suggestions have been given to develop a market for cross-border transactions, diversify fuel sources from non-renewable to renewable sources, energy efficiency and conservation, demand-side management, a suitable environment for private investment, soft loans for renewable energy, tariff adjustment, and technological advancement.

The experts also have exposed their implemented strategy. These are efficiency and conservative strategies and renewable energy-based power projects. To minimize wastage during pick-up hours, the price per unit increases and customers are encouraged to use energy-saving electrical devices. The respondents of Petrobangla urge finding an alternative fuel and minimizing gas dependency. They have suggested developing a coal field and importing CPG and LNG. The government has already signed contracts with Excelerate Energy Bangladesh Limited (EEBL) and Summit LNG Terminal Co. (Pvt.) Ltd. to build terminals at Moheshkhali and Matarbari. Both are now under construction.

When the stimulators have been justified along with the recommended strategies to meet the energy crisis, only one alternative solution has been proven: energy diversification in Bangladesh. More consumption needs more energy due to population density as the population increases geometrically. The unmet demand will be increased. Alongside, the depletion of the primary energy sources makes the deficiency horrible. The respondents have suggested importing fuel, but the fuel price has jumped in the last few decades. Cross-border transactions are a temporary solution as the world is now facing a shortage of fossil fuel and environmental degradation due to the usage of them. Energy efficiency and conservation can lead to a supply greater than its projection, which is not sustainable. On the other hand, if production is interrupted or even stopped, it is illogical to think about waste management policy. Soft loans, tariff adjustment, and technological advancement are also the supporting tools to diversify fuel (a mixture of non-renewable resources and renewable energy resources). These will be helpful for installing and maintaining the power units.

So, diversification is not only the solution in Bangladesh but all over the world to secure energy. All efforts should be given to the movement of different sources. To meet the present energy crisis, the government of Bangladesh has recently taken initiatives. The focus has been given to creating new sources of energy and

transferring nonrenewable to renewable energy dependency. The expansion plans of these selected companies show that they are moving towards a diversification strategy. They are slowly moving towards natural gas as opposed to imported fuel, i.e., LPG. Power and energy companies have entered into a diversification strategy by taking some projects, i.e., nuclear power plants, solar systems, etc.

Conclusion

Most of the power and energy companies in Bangladesh are dependent on natural gas, which is not a reliable source. Natural gas reserves are expected to last until 2031, according to a JICA statistical survey. Along with this, the respondents give the opinion that primary energy sources are not secured. The main problem facing the power and energy sectors is energy deficiency. Concurrently, primary energy sources are not available, affordable, and reliable. That negatively affects efforts to ensure energy security. Energy deficiency is now a major challenge to ensuring energy security. The stimulators, i.e., population density, private sector investment, depletion of primary energy sources, industrial structure, and composition of energy, have been identified as null hypotheses and accepted. The study results show that these stimulators are highly accountable for energy deficiency. The respondents have suggested ways to overcome this crisis. To meet this crisis, the best strategy is to find multiple sources of energy. Other suggestions, such as a favorable environment for private investment, low-interest loans for renewable energy, tariff adjustments, and technological advancement, are only auxiliary tools for carrying out the diversification strategy. Cross-border transactions, energy efficiency, conservation and demand-side management are the short-term solutions.

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*'রবীন্দ্র বিশ্ববিদ্যালয় পত্রিকা'*য় লেখার নিয়মাবলি

১. গবেষণা প্রবন্ধের কম্পোজ করা পাণ্ডুলিপির দুটি কপি ও একটি সিডি (CD) সরাসরি বা ডাকযোগে প্রেরণ করতে হবে।

২. প্রবন্ধের মূল পাঠ A4 কাগজে ১৪ পয়েন্ট বাংলা 'সুতন্বী এমজে' ফন্টে দুই লাইনের মাঝে ১.৫ ফাঁক রেখে দুই দিকে সমতা (justified) বিধান করে কম্পোজ করতে হবে।

৩. নিবন্ধের প্রথম পৃষ্ঠায় লেখার শিরোনাম, লেখকের নাম, প্রাতিষ্ঠানিক পরিচিতি/পদবি লিপিবদ্ধ থাকবে। মূল প্রবন্ধ শিরোনামসহ দ্বিতীয় পৃষ্ঠা থেকে শুরু হবে। দ্বিতীয় পৃষ্ঠায় লেখকের নাম থাকবে না।

৪. নিবন্ধের শব্দ সংখ্যা হবে অনধিক ১০,০০০ (দশ হাজার)।

৫. প্রবন্ধ বাংলা একাডেমি প্রণীত *আধুনিক বাংলা অভিধান*-এর বানান অনুযায়ী রচিত হওয়া বাঞ্ছনীয়।

৬. প্রবন্ধের শুরুতে ১০০ শব্দের সারসংক্ষেপ থাকতে হবে। বাংলা ভাষায় রচিত প্রবন্ধের সারসংক্ষেপ বাংলায় এবং ইংরেজি ভাষায় রচিত প্রবন্ধের সারসংক্ষেপ ইংরেজিতে লেখা বাঞ্ছনীয়।

৭. প্রবন্ধের মূল পাঠে অন্য কোনো উৎসের সংক্ষিপ্ত উদ্ধৃতি থাকলে তা একই অনুচ্ছেদে উদ্ধৃতি চিহ্ন (" ") ও সূত্রসহ উল্লেখ করতে হবে। তবে উদ্ধৃতিটি ২৫ শব্দের বেশি হলে তা মূল পাঠের নিচে বাঁ দিকে ১/৪ ইঞ্চি ভেতরে (indenting) ১২ পয়েন্টে নতুন অনুচ্ছেদে সূত্রসহ উল্লেখ করতে হবে। এক্ষত্রে উদ্ধৃতি চিহ্ন ব্যবহার করার দরকার নেই। কবিতার উদ্ধৃতিতে মূলের পঙ্‌ক্তিবিন্যাস অক্ষুণ্ন থাকবে। উদ্ধৃতির ক্ষেত্রে মূল বানানের পরিবর্তন হবে না।

৮. মূল পাঠে সারণি (table) ও চিত্রাদি থাকলে সেগুলোর পর্যায়ক্রমিক সংখ্যা (যেমন : ১, ২, ৩ ...) প্রদান করতে হবে। প্রত্যেক সারণি ও চিত্রের যথাযথ আখ্যা (caption) প্রদান জরুরি।

৯. মূল পাঠে কোনো বিষয় সম্পর্কে অতিরিক্ত ব্যাখ্যা প্রদান করতে চাইলে তা মূল পাঠের শেষে অন্ত্য-টীকায় (end-note) উপস্থাপন করতে হবে। এ ধরনের টীকা প্রদানের ক্ষেত্রে মূল পাঠের উদ্দিষ্ট ব্যাখ্যা বা বক্তব্য অধিসংখ্যা (superscript) দিয়ে ([১,২,৩] ইত্যাদি) নির্দেশ করতে হবে।

১০. অন্য কোনো লেখকের উদ্ধৃতি ব্যবহারের নিয়ম :

১৯৭৭ খ্রিষ্টাব্দে প্রকাশিত আবদুল মান্নান সৈয়দ-এর *নজরুল ইসলাম : কবি ও কবিতা* বইয়ের ২৫২তম পৃষ্ঠা থেকে উদ্ধৃত অংশটি নিম্নোক্তভাবে উপস্থাপিত হবে :

চিত্রকল্প প্রধানত বিষয়ের আত্মার চেয়ে বিষয়ের শরীর ফলিয়ে তোলার আকাঙ্ক্ষী। অনেক সময় উপমা, রূপক ও প্রতীক : কবিতার এই সব উপচারের ছদ্মপোশাক প'রে লুকিয়ে থাকে চিত্রকল্প; অবশ্য উপমা, ও প্রতীক মাত্রেই-যে চিত্রকল্প নয়—সে তো বলা বাহুল্য। (মান্নান, ১৯৭৭ : ২৫২)

১১. প্রবন্ধের মূল পাঠের শেষে একটি সহায়কপঞ্জি (reference) থাকবে। এই সহায়কপঞ্জিতে কেবল মূল পাঠে যেসব লেখক ও গ্রন্থের উল্লেখ আছে, তা বর্ণানুক্রমে (alphabetic order) বিন্যস্ত করতে হবে। বাংলা ও ইংরেজি গ্রন্থের জন্য স্বতন্ত্রভাবে সহায়কপঞ্জি রচনা করতে হবে, যেখানে প্রথমে বাংলা বই স্থান পাবে। সহায়কপঞ্জি রচনার নিয়ম নিম্নরূপ :

গ্রন্থ

আহমদ শরীফ (১৯৭৭)। *মধ্যযুগের সাহিত্যে সমাজ ও সংস্কৃতির রূপ*। মুক্তধারা, ঢাকা।

M. A. Rahim (2013). *The History of the University of Dacca*. Dhaka University, Dhaka.

গবেষণা পত্রিকা

আনোয়ার পাশা (১৩৭৫)। 'মোহামেডান লিটারারী সোসাইটি ও হিন্দুমেলা'। *সাহিত্য পত্রিকা*, দশম বর্ষ : দ্বিতীয় সংখ্যা, ঢাকা বিশ্ববিদ্যালয়, ঢাকা।

১২. গ্রন্থের একাধিক লেখক থাকলে তথ্যনির্দেশে সকলের নাম থাকতে হবে।

১৩. প্রকাশিত কিংবা প্রকাশের জন্য বিবেচনাধীন লেখা গ্রহণ করা হয় না।

১৪. প্রকাশের জন্য মনোনীত কিংবা অমনোনীত কোনো পাণ্ডুলিপি ফেরত দেওয়া হয় না। প্রবন্ধ প্রকাশিত হলে লেখক পত্রিকার দুটি কপি ও নিয়মানুযায়ী সম্মানি পাবেন।

প্রবন্ধ প্রেরণ ও যোগাযোগ

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