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# Time series ARIMA forecasting of natural gas consumption in Bangladesh's power sector

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**ABSTRACT**

This study summarizes the steps for forecasting Natural gas consumption in Bangladesh's power sector using Box-Jenkins autoregressive integrated moving average (ARIMA) time series model. For this study a structure for ARIMA forecasting model is being proposed where a time series is expressed in terms of past values of itself plus current and lagged values of a 'white noise' error term. Validity of the model was tested using standard statistical techniques and the best model is proposed on the basis of various diagnostic and selection & evaluation criteria. The findings of the study will provide policy makers in Bangladesh a long term perspective of natural gas consumption in power sector along with necessity of exploring other alternative energy sources and assist in adopting proper strategies to address the power supply situation of Bangladesh.



## Introduction

Commercial energy can be considered as backbone of a country's industrialization and economic growth. An accelerated economic growth cannot be achieved without a well-coordinate effort of both government and private sector in supplying public goods like roads, electricity, power, gas, etc. Currently power is one of the major problems towards expansion of the manufacturing sector in Bangladesh. The country has been facing a critical shortage of electricity for many years. Bangladesh plans to become a middle income country by 2020 and for this the growth projections were set to become 8+ percent by 2012. This means that the demand for electricity will increase annually by 11.2 percent at the minimum (using energy elasticity of 1.4 according to draft Sixth Five Year Plan, Bangladesh estimates). At this rate the production capacity of electricity in Bangladesh should double by every 6.5 years. This means annual net increase in generation capacity by 1,030 MW. Although there has been some major improvement in terms of generating capacity of electricity, the problem has not improved significantly. The only commercial energy resource that mainly supports power generation in Bangladesh is natural gas. As a result the gas fields are increasingly taking a lot of pressure in terms of production, consequently depleting at a faster rate.

During the last decade Bangladesh's natural gas production has raised significantly but still it failed to keep pace with demand. This production shortage has resulted in significant energy crisis especially in the electricity and industrial sector. Developing a reliable method to forecast Bangladesh's natural gas production and consumption will benefit gas producers, consumers and policy makers. In this power sector's gas consumption forecasting has been carried out to better analyze the future gas consumption in power generation of Bangladesh. Economic growth and energy consumption are closely related. A clear understanding of econometric relation between energy and economic demand can help Bangladesh to understand the implications of changes in the exogenous variables when the underlying relationships are fairly stable. An understanding of broader impacts of energy use can be of great help in designing better energy policies, at least at the macro level.

## Literature Review:

Several methods for identifying ARIMA models have been suggested by Box- Jenkins and others. Makridakis et al. (1982), and Meese and Geweke (1982) in their writings have discussed the methods of identifying univariate models. Among others Jenkins and Watts (1968), Yule (1926, 1927), Bartlett (1964), Quenouille (1949), Ljune and Bos (1978) and Pindyck and Tubinfeld (1981) have also emphasized the use of ARIMA models. It was the major contribution of Yule (1927) which launched the notion of stochasticity in time series by postulating that every time series can be regarded as the realization of a stochastic process. Based on this idea, a number of time series methods have been proposed. George E.P. Box and Gwilym M. Jenkins (1970) integrated the existing knowledge on time series with their book "Time Series Analysis: Forecasting and Control". First of all, they introduced univariate models for time series which simply made systematic use of the information included in the observed values of time series. This offered an easy way to predict the future development of the variable. Moreover, these authors developed a coherent, versatile three-stage iterative cycle for time series identification, estimation, and verification. George E.P. Box and Gwilym M. Jenkins (1970) book had an enormous impact on the theory and practice of modern time series analysis and forecasting. With the advent of the computer, it popularized the use of autoregressive integrated moving average (ARIMA) models and their extensions in many areas of science. Since then, the development of new statistical procedures and larger, more powerful computers as well as the availability of larger data sets has advanced the application of time series methods. After the introduction by Yule (1921), the autoregressive and moving

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average models have been greatly favored in time series analysis. Simple expectations models or a momentum effect in a random variable can lead to AR models. Similarly, a variable in equilibrium but buffeted by a sequence of unpredictable events with a delayed or discounted effect will give MA mode.

The analysis of time series helps to detect regularities in the observations of a variable and derive 'laws' from them, and/or exploit all information included in this variable to better predict future developments. The basic methodological idea behind these procedures, which were also valid for the Babylonians, is that it is possible to decompose time series into a finite number of independent but not directly observable components that develop regularly and can thus be calculated in advance. In the middle of the 19th century, this methodological approach to astronomy was taken up by the economists Charles Babbage and William Stanley Jevons. The decomposition into unobserved components that depend on different causal factors, as it is usually employed in the classical time series analysis, was developed by Warren M. Persons (1919). Russian statistician Evgenij Evgenievich Slutzky and the British statistician George Udny Yule at the beginning showed that time series with cyclical properties similar to economic (and other) time series can be generated by constructing weighted or un weighted sums or differences of pure random processes. E.E. Slutzky and G.U. Yule developed moving average and autoregressive processes as models to represent time series. Herman Wold (1938) systematized and generalized these approaches in his doctoral thesis. Their widespread practical usage is due to George E.P. Box and Gwilym M. Jenkins (1970), who developed methods to implement these models empirically. They had abandoned the idea of different components and assumed that there was a common stochastic model for the whole generation process of time series. Firstly, this method identifies a specific model on the basis of certain statistical figures. Secondly, the parameters of this model are estimated. Thirdly, the specification of the model is checked by statistical tests. If specification errors become obvious, the specification has to be changed and the parameters have to be re-estimated. This procedure is re-iterated until it generates a model that satisfies the given criteria. This model can finally be used for forecasts.

Highlighting about the existing academic work done on energy sector of Bangladesh, in comparison with other deregulated industries such as Garments, telecommunications the forecasting literature in energy sector especially in gas sector is very rare in Bangladesh Most of the studies regarding gas production; consumption is being conducted considering the demand for gas in electricity production of Bangladesh. Moin Uddin(2004) conducted a study on Expected status of natural gas in Bangladesh in meeting the electricity demand in the next twenty five years. In that paper the author presents an assessment of the amount of gas required to produce electricity in coming 25 years. In the assessment procedure the study considers other natural resources and imported fuels for producing electricity. The assessment is based on the forecasting of electrical energy obtained from the forecasted hourly electrical demands. The paper shows that Bangladesh will not be able to meet its own demand; rather it will have a deficit. The deficit range is 14.28 to 17.79 TCF.

Regarding the Gas sector, a good number of technical bodies worked in the past at various levels to assess the national requirement and utilization of gas in different end use sectors for various durations. The extent of Govt. control in the gas production, distribution sector can be attributed to this lack of research work on this important sector of Bangladesh as there exist shortage of published data from the regulators. As these studies by various govt. authorities are mainly carried out for planning purposes only a few were actually published later on. Various approaches were made in the past to forecast the energy consumption requirement, production in various sectors of Bangladesh. National Energy Policy (NEP), a Government body, forecasted the energy need of the country from 2000 to 2020. The expected energy generation for a long term (2000-2015) is forecasted in Power System Master Plan (PSMP) of Bangladesh Power Development Board (BPDB). It uses the forecasted yearly peak and constant load shape as the basic load model. Rodekohr(2008) projected future demand of natural gas for five different scenarios considering economic growth, energy intensity of GDP and the share of gas in total commercial energy. Ministry of Energy and Mineral Resources of the Government of Bangladesh employed the methodology based on energy intensity (EI) of the economy. They considered four models and four GDP growth rates (3%, 4.55%, 6% and 7%) in the projections. The essence of the technique adopted is the projection of the past trend to forecast the future.

The Ministry of Energy and Mineral Resources projected the natural gas demands for the nation considering two projection time frames: that is, up to 2020 and up to 2050 respectively .However, it did not carry out any sectoral analysis and its projection of the requirement of natural gas. Petrobangla projected the natural gas demand in the power sector of Bangladesh for fifty years (2001-2050). . Over the next two decades, demand is predicted to increase at six percent per year, especially in the industrial and household consumption sectors, shifting the demand shares for 2012 to a projected 51 percent for power, 11 percent for fertilizer, and 38 percent for other industrial, commercial and household purposes. Petrobangla's official estimates put the known discovered reserve of natural gas at 29 trillion cubic feet in 23 gas fields. Of this amount, 21 trillion cubic feet are considered to be recoverable. The government has referred recently to 13.5 trillion cubic feet of proven and recoverable gas reserves. The U.S. Geological Survey estimated that Bangladesh has potentially 32 trillion cubic feet of undiscovered reserves. Despite these differences in estimates of Bangladesh's natural gas reserves and the general uncertainty related to any such number, it is clear that Bangladesh would be able to satisfy its demand for natural gas over the medium-term if the shortcomings regarding gas exploration can be reduced drastically.

Unlike in Bangladesh, in other advanced economics several important works have been done in gas production, forecasting along with official work by various energy authorities. Serletis and Herbert (1999) employed cointegration analysis and detect effective arbitraging mechanisms for the price, consumption, production of natural gas. Lien and Root (1999) estimate a persistence profile of impulse response in natural gas market. They suggest that the persistence of a shock, or the time for the prices to converge to long-run equilibrium, increases with contract length. MacAvoy and Moshkin (2000) conduct simulations with a partial equilibrium model of the natural gas industry.

Liu and Lin (1991) forecasted the residential gas consumption, demand in Taiwan. They identified two important natural gas consumption determinants: temperature of service areas and natural gas prices. Van Groenendaal (1995) forecasts demand for natural gas by the manufacturing sector in Indonesia. Changes in economic structure and energy prices are considered key variables in explaining demand, gas production there. Christodoulakis et al. (2000) derived demand equations by economic sector and type of energy for Greece while forecasting the impact of demand changes on CO2 emissions.

**Data and Methodology**

In this paper, historical monthly gas consumption data in power sector of Bangladesh (1980-2008) will be analyzed to conduct a univariate time series ARIMA forecasting of the gas consumption in power sector in Bangladesh up to year 2014. The historical data's are mainly collected from Bangladesh Bureau of Statistics and Petrobangla. A time series model is useful in examining the dynamic determinants of production, demand or supply. The basic underlying assumption in time series forecasting is that the set of casual factors (Macroeconomic fundamentals) that operated on the dependent variable in the past will exhibit similar influence in some repetitive fashion in the future. The basic idea in developing univariate forecasting models is to somehow extract a mathematical model that will pattern this behavior. The advantage of time series models is that they can convey information about how supply or demand relationships have varied historically, and where particular "structural breaks" in certain trends have occurred. These models are equally useful as a starting point for forecasting since most forecasts are developed from historical trend relationships. The main disadvantage of time series model is that data availability usually limits the range of the determinants measuring the supply or demand relationship. Specially for a country like Bangladesh with its independence in 1971 and backdated data management process availability of data becomes a major issue.

The objective of analyzing economic data is to predict or forecast the future values of economic variables. In a series of articles and a subsequent book, Box and Jenkins (1970) describe in detail a strategy for the construction of linear stochastic equations describing the behavior of a time series. Box-Jenkins introduced a methodology is to fit data using ARIMA model. ARIMA approach combines two different parts into one equation; they are the Autoregressive process and Moving average process. The autoregressive process (AR) is one where the current value of the variable (Yt) is a function of its past values plus an error term; as in:

$Y_t = f\,(Y_{t-1}, Y_{t-2}, \ldots\ldots\ldots\ldots, Y_{t-k})$

Where Yt is the variable is being forecasted, p is the number of the past values used and u is the error term and normally distributed. The AR process can be written in lag operator form as:

$\theta\,(_L)Y_t = \beta + \mu_t$

Where, $\theta\,(L) = (1 - \theta_L - \theta\,L_2 + \ldots\ldots\ldots\ldots + \theta_p\,L_p)$

A moving average process assumes the current value of the variable Yt as a function of the past values of the error term plus a constant. A moving average of order (q), MA (q) is expressed as:

$Y_t = ft\,(\varepsilon_{t-1}, \varepsilon_{t-2} \ldots\ldots\ldots\ldots, \varepsilon_{t-q})$

The proposed BJ methodology involves iterative three-stage cycles. The first step requires model identification. This stage the researcher should determine the order of autoregressive, integration and moving average (p,d,q) of the ARIMA model with aid of Correlogram and partial Correlogram. Having identified the values of ARIMA model, the second step is Diagnostic Checking. This stage involves a series of statistical testing to ensure the accuracy of ARIMA model selection, that the chosen ARIMA model fits the data well, for it is possible model that another model might fit the data better. One simple test to ensure the chosen model is to test the residuals estimated from this model whether or not they are white noise. If the residuals turned out to be white noise, then one accepts the particular fit; otherwise, one should restart over the selection process. The third step is the Estimation of the parameters of the selected autoregressive and moving average forms include in the model. The final step in the procedure is Forecasting. This step involves forecasting future value of the variable based on the ARIMA model. To complete the work, the accuracy of forecasting should be investigated. A number of statistical measures are available for this purpose. They are mean error (ME), mean absolute error (MAE), mean square error (MSE), mean percentage error (MPE), and mean absolute percentage (MAPE) and Theil's Ustatistic to compare the accuracy of various models.

To employ Box-Jenkins process to forecast a time series, the stationarity of the series must be maintained. Therefore, the first step in the process begins with testing for stationarity of the series. A time series is said to a stationary if both the mean and the variance are constant over time and the autocorrelation at two different time periods. The stationarity test examines the properties of the time series variable, in order to have a reliable regression tests to make sure that the model could not be subjected to "Spurious Regression". The problem of spurious regression arises because time series data usually exhibit non-stationary tendencies and as a result, they could have non-constant mean, variance and autocorrelation as time passes. This could lead to non-consistent regression results with misleading coefficients of determination (R2) and other statistical test.

In practical term, to make the series stationary requires performing three processes: removing the trend, having a constant variance and finally, removing the seasonality. First differencing the data removes the trend and makes the variance constant. The visual representation, Correlogram analysis where non-stationary series is having a slowly decaying ACF and PACF, Philips- Perron test and the unit-root tests of the data provide the tool for determining whether the series is stationary or notA plot of the series against time gives an idea about the characteristics of the series. If the time plot of the series shows that the data scattered horizontally around a constant mean, then the series is stationary at it levels. On the other hand if the time plot is not horizontal the series is non-stationary. Equivalently, the graphical representation of the autocorrelation functions (ACF & PACF) can be employed to determine the stationarity of the series. If the ACF and PACF drop to or near zero quickly, this indicates that the series is stationary. If the ACF and PACF do not drop to zero quickly, then the non-stationarity is applied to the series.

The order of integration (d) identified the differencing times to make the series stationary and the series contains (d) unit roots and the series is said to be integrated of order (d). If d=0, the series is said to be integrated of degree zero and stationary at level.

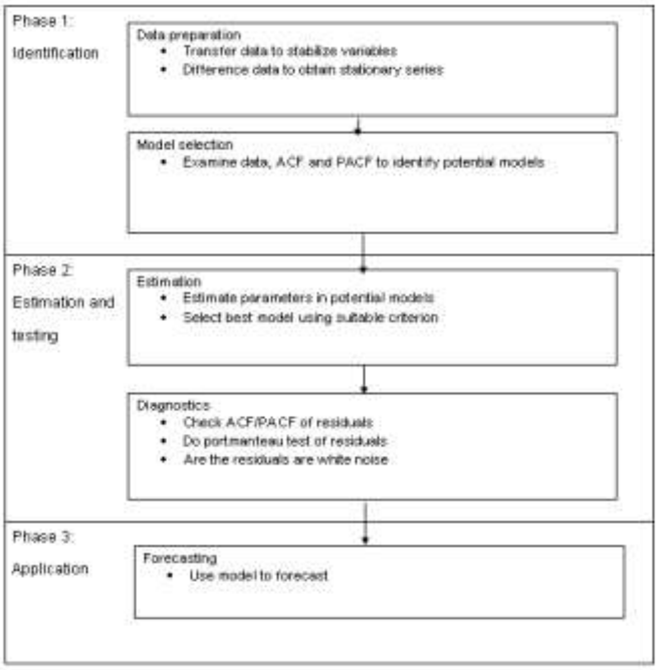
The augmented Dickey-Fuller test is based on the estimate of the following regression: ADF (p); without deterministic trend where (p) is the number of Augmentation terms included in ADF test

$(\Delta\,Y_{t-1} \ldots \Delta\,Y_{t-p})$

$\Delta\,X = \alpha 0 + \alpha 2Xt\text{-}1 \ldots\ldots\ldots\ldots\ldots + \varepsilon t$

P= is the number of lags which should be large enough to ensure the error terms are white noise process and small enough to save degrees of freedom. The number of lags can be determined and will be chosen based on the AIC and SBC selection. The error term is normally distributed. If the t-ratio of the estimated coefficient is greater than the critical t-value, the null hypothesis of unit root (nonstationary variable) is rejected indicating the variable is stationary at level and integrated of degree zero denoted by I(0). On the hand if the series found to nonstationary at levels, a transformation of the variable by differencing is need until we achieve stationarity that is non-autocorrelated residuals.

**Figure 1: Schematic representation of the Box-Jenkins methodology for time series modeling**




**Discussion**

A time series is a sequence of observations ordered in time. The intrinsic nature of a time series is that successive observations are dependent or correlated. Statistical methods that rely on independent assumptions are, therefore, not applicable. Time series analysis studies the stochastic mechanism of an observed series. The study of time series can assist in understanding and describing the underlying generating mechanisms of a data series which facilitates in forecasting future values and to estimate the impact of events or policy changes. Results from analysis can give valuable information when formulating future policies. Currently formulating future gas sector planning is a key issue for Bangladesh highlighting its importance in Bangladesh's economy. To solve current energy crisis and thereby ensure smooth development process there is no other alternative but to rethink about Bangladesh's energy planning process and integrate advanced econometric approaches to get more insights in the consumption pattern, planning etc.

**Univariate Model for Power Sector**

**Identification**

For time series, the most obvious graphical form is a time plot in which the data are plotted over time. The basic features of the data including patterns and unusual observations are most easily seen through graphs. So to identify the best forecasting model, it is important to focus on the gas consumption pattern of Bangladesh

**Stationarity Test**

The foundation of time series analysis is stationarity. Trends or other non stationary patterns in the level of a series, results in positive autocorrelation that dominate the autocorrelation diagram. Therefore, it's important to remove the non stationarity, so other correlation structure can be seen before proceeding with time series model building. One way of removing non stationarity is through the method of differencing.
Unit Root test has been conducted to find out the stationarity of gas used by the power generation series.. For the Unit Root test the method that we use is the Augmented Dickey Fuller Test (ADF). Here, for inference, the null and the alternatives are:
**$H_o$:** Power sector's gas consumption have unit root;
$H_a$: **Power sector's gas consumption do not follow unit root;**

**Table 1: Unit root test output**

| | | | t-Statistic | Prob.* |
|---|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | | 3.750388 | 1.0000 |
| Test critical values: | 1% level | | -3.450411 | |
| | 5% level | | -2.870274 | |
| | 10% level | | -2.571493 | |

**Multiplicative Decomposition:**

Many forecasting methods are based on the concept that when an underlying pattern exists in a data series, that pattern can be distinguished from randomness by smoothing (averaging) the past values. Decomposition methods usually try to identify two separate components of the basic underlying pattern that tend to characterize economic and business series. These are trend cycle and the seasonal factors. As the consumption series is exhibiting seasonal variation along with trend component multiplicative decomposition method has been used to decompose the time series into its trend, seasonal, cyclical components.
Decomposition assumes that the data are made up as follows

**Data= pattern+ error**

**=f (trend cycle, seasonality, error)**

Thus, in addition to the components of the pattern, an element of error or randomness is also assumed to be present. This error is assumed to be the difference between the combined effect of the two sub patterns of the series and the actual data. The process begins by calculating the moving average and centered moving average. The purpose behind computing these averages is to eliminate seasonal variations and irregular fluctuations from the production series data set.

**Table 2: Output Table for Forecasting Model**

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| S1 | -0.400986 | 4.434564 | -0.090423 | 0.9280 |
| S2 | -8.819805 | 4.450701 | -1.981666 | 0.0484 |
| S3 | 33.19872 | 4.450186 | 7.460073 | 0.0000 |
| S4 | -12.33778 | 4.374174 | -2.820597 | 0.0051 |
| S5 | 4.833593 | 4.372265 | 1.105512 | 0.2698 |
| S6 | -1.462577 | 4.371918 | -0.334539 | 0.7382 |
| S7 | -3.442821 | 4.374239 | -0.787067 | 0.4318 |
| S8 | 12.02362 | 4.376122 | 2.747552 | 0.0063 |
| S9 | -12.37980 | 4.378320 | -2.827523 | 0.0050 |
| S10 | 3.406510 | 4.380458 | 0.777661 | 0.4373 |
| S11 | -10.66974 | 4.382665 | -2.434533 | 0.0155 |
| S12 | 4.571592 | 4.384889 | 1.042579 | 0.2979 |
| TSQ | 3.91E-05 | 2.67E-05 | 1.463766 | 0.1442 |

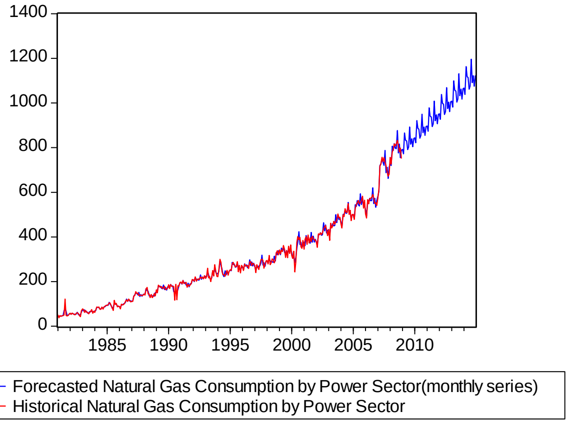
**The final composite model for Gas consumption series of power sector of Bangladesh is as follows:**

Gas Consumption in power sector$_{t\ (1^{st}\ \text{differenced})}$ = $\beta_1$ tsq + $\beta_2$ January$_t$ + $\beta_3$ February$_t$ + $\beta_4$ March $_t$ + $\beta_5$ April $_t$ + $\beta_6$ May$_t$ + $\beta_7$ June$_t$ + $\beta_8$ July$_t$ + $\beta_9$ August$_t$ + $\beta_{10}$ September$_t$

$$+\beta_{11}\ \text{October}_t + \beta_{12}\ \text{November}_t + \beta_{13}\ \text{December}_t + \beta_{14}\ \text{AR(1)} + \beta_{15}\,\text{AR(2)} + \in_t$$

**Figure 1: Time series plot of natural gas consumption in power sector (($10^6$ cu meter)**

**Source: Bangladesh Bureau of statistics**




Power production Bangladesh is mainly based on the transformation of natural gas. BPDB is the main producer of electricity, but production is inefficient. Generators are mainly based on old vintage technology, while proper maintenance is not undertaken. Lack of available reserve capacity has meant that frequently generators cannot be shut down for much needed repair maintenance work. The problem is compounded by the difficult financial situation of BPDB. Extensive load shedding, system loss and low collection ratios underscore these problems. Only about 25 per cent of the Bangladeshi population has any access to electricity. This low access ratio is one of key reason behind sluggish poverty reduction in Bangladesh. Electricity and the associated system and organization have been considered one of the most important developments of the 20th century. Economic development has been intrinsically coupled to electricity use. Lack of electricity is usually associated with poverty and reduced quality of life.

**Table 3: Forecasted natural gas consumption in power generation in of Bangladesh (2012-2014)**

| Date | Forecasted consumption by power sector($10^6$ cu meter) |
|---|---|
| 2012M01 | 952 |
| 2012M02 | 927 |
| 2012M03 | 1038 |
| 2012M04 | 998 |
| 2012M05 | 995 |
| 2012M06 | 948 |
| 2012M07 | 962 |
| 2012M08 | 1069 |
| 2012M09 | 975 |
| 2012M10 | 1004 |
| 2012M11 | 962 |
| 2012M12 | 1005 |
| 2013M01 | 1009 |
| 2013M02 | 982 |
| 2013M03 | 1099 |
| 2013M04 | 1057 |
| 2013M05 | 1053 |
| 2013M06 | 1004 |
| 2013M07 | 1018 |
| 2013M08 | 1131 |
| 2013M09 | 1032 |
| 2013M10 | 1062 |
| 2013M11 | 1017 |
| 2013M12 | 1064 |
| 2014M01 | 1067 |
| 2014M02 | 1038 |
| 2014M03 | 1163 |
| 2014M04 | 1118 |
| 2014M05 | 1114 |
| 2014M06 | 1062 |
| 2014M07 | 1076 |
| 2014M08 | 1196 |
| 2014M09 | 1091 |
| 2014M10 | 1123 |
| 2014M11 | 1075 |
| 2014M12 | 1124 |

## Conclusion

Under the current energy crisis of Bangladesh, the preferred method of recovering energy stored in the gas is by converting it into electricity which then opens a broad range of opportunities for improvement in home conditions; use of electric equipment in small manufacturing; climate control of commercial buildings, hospitals, and schools; and street lighting. Bangladesh, like many other emerging economies, manifests a direct relationship between growth in GDP and the generation of electricity. The balance between gas production capacities and electrical energy power generation needs to be well planned so as not to saddle the country with unproductive debt through power plants with unreliable gas supply, or electricity generation capacities incapable of covering the cost of fuel and capital consumed.

Gas pricing needs to provide requisite assurance to the domestic production and delivery systems of sufficient funds for sustainable growth and reliable service. In an open market economy, the stability of an economic entity as large as the Bangladesh gas sector cannot be assured without profitability and revenue growth. Many countries have tried, over the past decades, to balance the market economy dictate with the political and social demands of the constituency. One of the dangerous results of excessive yielding to social-engineering and techno-economic pressures leading to operations below the long-term marginal cost, is a downward spiral effect. An artificially low price stimulates an increase in demand, thus increasing production and delivery pressures. These results in an increase in operational costs and losses, thus providing a disincentive for future investment needed to keep the growth of supplies and the reliability of the delivery system.

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