Future Scenarios for the Bangladesh Petroleum Sector Development

Under

Strengthening of Hydrocarbon Unit in the

Energy and Mineral Resources Division (Phase-II)

ADB Grant 0019: GTDP

Prepared for:

HYDROCARBON UNIT

Energy and Mineral Resources Division

Government of the People's Republic of Bangladesh

Originally submitted: October 10, 2011
Revised: June 5, 2012

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1 EXECUTIVE SUMMARY

This is a revised version of the report incorporating responses to comments by Petrobangla and BGFCL that were received in April 2012.

This is a report on Future Scenarios for the Petroleum Development Sector in Bangladesh with a primary focus on natural gas demand and supply. It has been prepared under ADB Grant 0019: GTDP as a part of the project entitled "Strengthening of Hydrocarbon Unit in the Energy and Mineral Resources Division (Phase-II)".

The report begins with a review of historical gas consumption in Bangladesh and four previous gas demand forecasts. It also presents three new demand forecasts for Bangladesh gas demand and consumption. In this report, the word demand means total consumption of natural gas. Historical gas demand/consumption has been measured. Projections of future demand assume that gas will be available from various sources to meet that demand.

Actual gas consumption in Bangladesh has grown by an average of 10.0% per year from fiscal year (FY) 1980[1] to FY 2009. The average daily gas consumption in FY 2009 was 1936 MMCF per day. The annual consumption in that fiscal year was about 706 BCF. The previous gas demand forecasts that were reviewed tended to underestimate future gas demand. It is difficult to predict future gas demand accurately. This report considers three demand growth scenarios, each starting with actual FY 2009 gas consumption: a base gas case with demand growth of 7.3% per year, a low case with growth of 5.7% per year, and a high case with growth of 8.9% per year. The growth rate in each of these scenarios is lower than the long run historical average. This is reasonable, since the historical growth started with a very low rate of gas use in the country.

[1] Fiscal year 1980 runs from July 1, 1980 through June 30, 1981.

The report considers several actual and possible sources of gas:

- Existing fields
- New conventional fields
  - Mapped prospects and leads
  - Unmapped prospects and leads
  - Thin beds
- Unconventional sources
  - Coal bed methane (CBM)
  - Shale gas
- Gas imports
  - LNG
  - Pipelines

It also briefly mentions other energy sources including coal, LPG, petroleum products, renewable energy, and nuclear power.

The country has been experiencing shortages of natural gas. Since much of the power generation in the country is gas-fired, the gas shortages have caused power load shedding during certain seasons. This has heightened awareness of the need to explore for and develop new sources of natural gas.

There is also awareness of the potential for reform of end-user tariffs for natural gas to moderate demand for natural gas. Residential consumers pay a low fixed monthly fee for natural gas regardless of actual gas consumption. Other categories of gas consumers also pay a low price for gas. Tariff reform is being considered, which could lead to lower growth rates in gas demand.

Besides the range of future demand scenarios, the report presents a range of possible supply scenarios. Exploration and development of hydrocarbons is an intrinsically uncertain undertaking. There is uncertainty about whether a particular prospect, lead or target will contain commercial amounts of hydrocarbon, and if so, the quantity of hydrocarbon reserves or resources. There is also uncertainty about the timing of exploration activity and the rate of production from existing fields and new discoveries. We have built a probabilistic spreadsheet tool that models all of this uncertainty. The probabilistic inputs for the model are based on the Gustavson reserve and resource reports that were prepared earlier as part of this project.

The model predicts that there will continue to be small gas shortages over the next five years. Additional development is planned for existing fields, which will lead to increases in the supply of gas. However, the increases are not anticipated to keep pace with the increased demand for natural gas. We predict that domestic gas supplies will begin to fall substantially short of demand starting in about 2016, as production from existing fields goes on decline due to depletion of reserves within those fields. It is possible that large discoveries of shale gas may meet gas demand in late years after about 2024, but this is not assured.

The country has several options for dealing with the anticipated shortage in the domestic supply of natural gas, including:

- Accelerate natural gas exploration activity on the part of Petrobangla and/or international oil and gas companies
- Import natural gas as LNG, which will require construction of one or more LNG regasification facilities
- Arrange for import of natural gas by pipeline from neighboring countries
- Raise end-user prices for natural gas to moderate the demand
- Allow for more private sector involvement in the natural gas sector, for example allowing gas producers to sell gas to end users, with Petrobangla being compensated for providing transportation from the wellhead to the end user
- Consider fuel options other than natural gas
- Increase LPG supply to meet domestic demand.
- Initiate studies of unconventional gas (shale gas and coalbed methane) and thin beds in Bangladesh

A subsequent report on activity planning provides more detail about options to accommodate future energy needs in Bangladesh.

2 INTRODUCTION

Gustavson Associates (GA) has been working on behalf of the Hydrocarbon Unit in Bangladesh under ADB Grant 0019: GTDP on a project entitled Strengthening of Hydrocarbon Unit in the Energy and Mineral Resources Division (Phase-II). As part of this project, GA has previously prepared reports describing and quantifying the gas reserves and resources in Bangladesh.

This report uses those assessments to make predictions about future scenarios for natural gas consumption and supply in the country.

This is the final version of the Future Scenarios report. It incorporates comments received from Petrobangla and BGFCL based on their review of the draft version of the report, which was completed in December 2011.

3 BANGLADESH GAS DEMAND FORECASTS

3.1 INTRODUCTION

Natural gas is an abundant indigenous energy resource in the People's Republic of Bangladesh. Bangladesh's natural gas reserves have been estimated at roughly 18.8 trillion cubic feet (TCF) as of January 1, 2011.[2] With almost 90% of the country's power plants being gas based, the power sector is the largest user of natural gas in Bangladesh. The relative abundance of natural gas in Bangladesh as well as the low end-user prices has led to the inefficient and wasteful use of the resource. This has caused supply shortages throughout the country. Load shedding is a common occurrence in Bangladesh, reaching nearly 1000 MW per day.[3]

Bangladesh has small amounts of discovered oil. Other energy sources such as solar and nuclear power are slowly being introduced. Solar energy eclipsed the 1 million homes powered mark in 2011. Yet the demand for natural gas has more than doubled in the past decade. Similar demand growth is expected to continue into the future. Bangladesh consumed 349 billion cubic feet (BCF) of natural gas in Fiscal Year (FY) 2000 and 707 BCF in FY 2009.[4] The corresponding average daily rates of consumption were 956 MMCF per day and 1,936 MMCF per day respectively. Consumption increased by 102%, reflecting a compound annual growth rate (CAGR) of 8.1%.

This chapter presents historical Bangladesh gas consumption data, reviews four previous natural gas demand forecasts, and presents three new gas demand forecast scenarios. The four previous forecasts are:

1. Wood Mackenzie, "Preparation and Development of Gas Sector Master Plan, 2006."
2. ECON Analysis, "Bangladesh Optimal Gas Utilisation, 2004."
3. Global Data, "Gas Market Outlook in Bangladesh, 2010."
4. Technoconsult International, "Preparing the Gas Sector Development Program, 2009". (This report is an analysis of Petrobangla's official demand forecast).

[2] Source: Gustavson Associates, 2010.
[3] Source: The Daily Star, 2011
[4] Source: Petrobangla Annual Report, 2009

3.2 HISTORICAL GAS DEMAND

This section presents historical gas demand in Bangladesh from FY 1980 to FY 2009. Gas consumption figures were compiled from two sources, the U.S Energy Information Administration (EIA) and Petrobangla. Table 3-1 shows the annual consumption and annual average daily consumption rates from both sources. There are small differences in the reported consumption between the sources. The cause of the differences in the historical data is unknown.

The EIA information shows annual demand rising from 54.8 BCF in FY 1980 to 697.5 BCF in FY 2009. This represents a compound annual growth rate (CAGR) of 9.2%. The corresponding annual average daily gas consumption in Bangladesh grew from 150 MMCF per day to 1,911 MMCF per day.

Petrobangla's figures show annual consumption rising from 44.0 BCF in FY 1980 to 706.5 BCF in FY 2009. This represents a CAGR of 10.0%. The corresponding average daily gas consumption grew from 120.5 MMCF per day to 1,935.5 MMCF per day. Figure 3-1 and Figure 3-2 are graphical representations of the information provided in Table 3-1

Table 3-1 Historical Gas Consumption in Bangladesh

	U.S. ENERGY INFORMATION ADMINISTRATION		PETROBANGLA	
Fiscal Year	**Annual Consumption (BCF)**	**Avg. Daily Consumption (MMCFD)**	**Annual Consumption (BCF)**	**Avg. Daily Consumption (MMCFD)**
1980	54.8	150.2	44.0	120.5
1981	62.3	170.8	59.6	163.3
1982	66.8	183.0	64.7	177.3
1983	81.8	224.1	70.6	193.4
1984	97.5	267.1	86.6	237.3
1985	106.5	291.8	99.4	272.3
1986	122.2	334.7	115.6	316.7
1987	140.7	385.5	141.0	386.3
1988	157.2	430.5	146.4	401.1
1989	163.1	446.9	159.1	435.9
1990	167.5	458.9	164.1	449.6
1991	189.6	519.5	178.5	489.0
1992	211.0	578.1	194.5	532.9
1993	225.3	617.3	212.1	581.2
1994	247.6	678.2	235.6	645.4
1995	264.9	725.6	254.6	697.6
1996	269.5	738.2	245.8	673.4
1997	279.5	765.8	266.6	730.3
1998	304.6	834.5	292.1	800.3
1999	331.1	907.1	306.9	840.7
2000	353.2	967.5	348.8	955.5
2001	377.9	1035.3	364.6	999.0
2002	410.5	1124.8	400.8	1098.1
2003	445.9	1221.5	427.5	1171.3
2004	478.5	1311.0	457.6	1253.7
2005	517.7	1418.4	505.1	1383.9
2006	557.8	1528.2	535.8	1467.8
2007	603.4	1653.0	584.5	1601.3
2008	664.8	1821.4	643.9	1764.2
2009	697.5	1911.0	706.5	1935.5

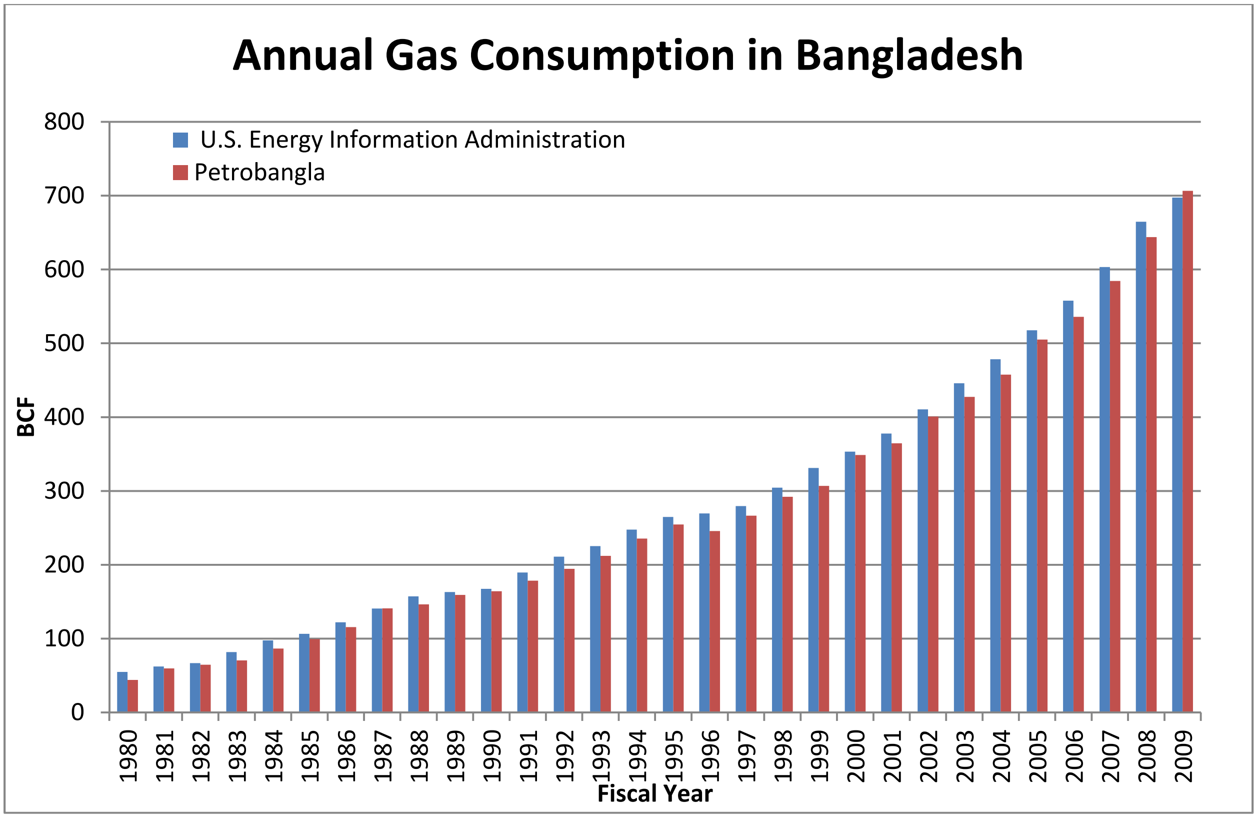


Figure 3-1 Historical Annual Gas Consumption Bangladesh

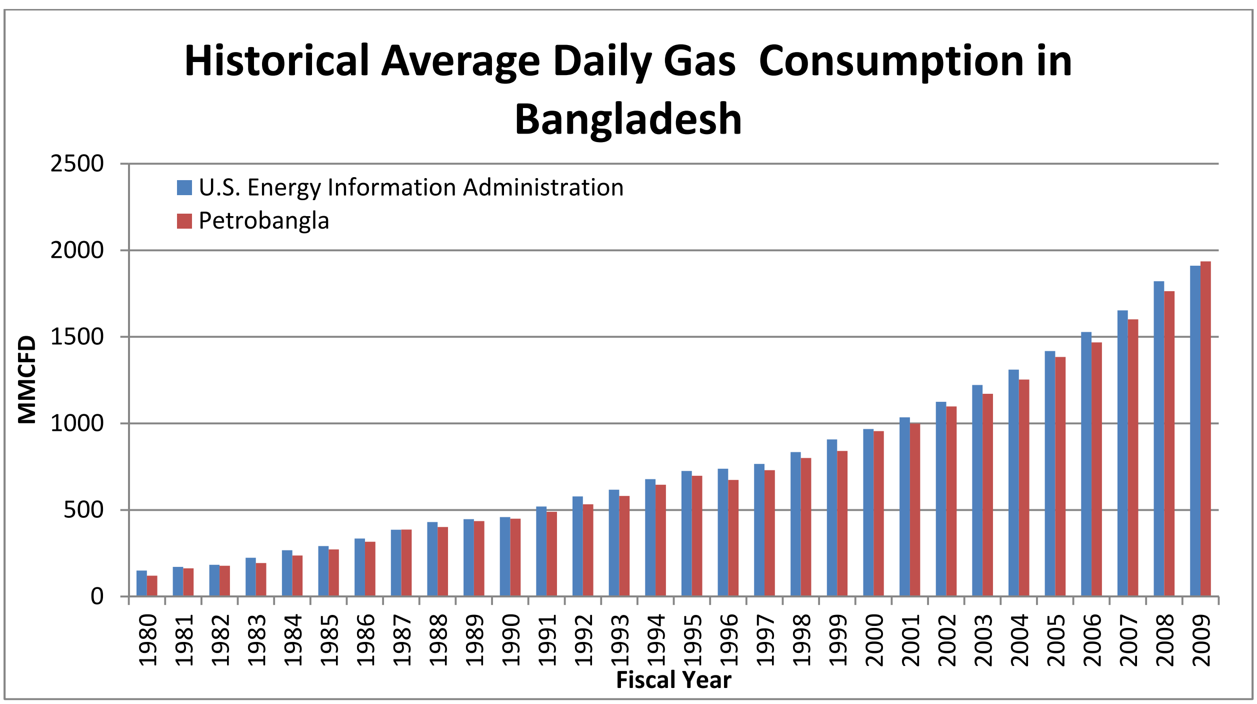


Figure 3-2 Historical Average Daily Gas Consumption Bangladesh

3.3 SUMMARY OF PREVIOUS FORECASTS

This section compares four previous forecasts of natural gas demand in Bangladesh. The four previous demand forecasts were:

1. Wood Mackenzie, "Preparation and Development of Gas Sector Master Plan, 2006."
2. ECON Analysis, "Bangladesh Optimal Gas Utilisation, 2004."
3. Global Data, "Gas Market Outlook in Bangladesh, 2010."
4. Technoconsult International, "Preparing the Gas Sector Development Program, 2009". (This report is an analysis of Petrobangla's official demand forecast).

The four previous demand forecasts were prepared between 2004 and 2010. The range of gas demand forecast for FY 2020 ranges widely from 2.0 to 4.7 BCF per day.

All of the previous studies concluded that the power sector is the largest gas consumer in Bangladesh and that demand was expected to rise significantly in the future. The power sector's share of total gas demand in Bangladesh was forecast to increase over time.

Natural gas is also used as a feedstock for fertiliser production in Bangladesh. While the fertiliser sector is a significant user of natural gas in Bangladesh, only small growth is projected in fertiliser production capacity. Due to slow production growth, the fertiliser sector's share of total gas demand is expected to fall over time.

The Wood Mackenzie and ECON Analysis forecasts each include three possible future demand scenarios. The Petrobangla and Global Data forecasts present only a single scenario.

Table 3-2 is a comparison of the previous gas demand forecasts. All demand figures in this table are for FY 2020. Wood Mackenzie forecasts compound annual demand growth rates between 5.3% and 8.7% for the period FY 2005-2020. ECON Analysis forecasts CAGR between 3.4% and 5.9% over the same time period. Petrobangla forecasts a CAGR of 7.3% for the Period FY 2009-2020. Global Data forecasts a CAGR of 4.3% over the period FY 2005-2010.

Table 3-2 Comparison of Total Forecasted Natural Gas Demand in 2020

	WOOD MACKENZIE			ECON ANALYSIS			PETROBANGLA	GLOBAL DATA
CASE	**LOW**	**BASE**	**HIGH**	**LOW**	**BASE**	**HIGH**	**Base**	**Base**
Demand (mmcfd)	3125	4112	5193	1960	2622	3182	4115	2698
CAGR	5.3%	7.1%	8.7%	3.4%	4.9%	5.9%	7.3%	4.3%

Figure 3-3 shows a comparison of the four previous gas demand forecasts as well as actual historical gas consumption (using Petrobangla data). Actual annual average gas consumption in FY 2009 was 1,936 MMCF per day. The Wood Mackenzie base forecast was nearly in line with actual consumption over the period FY 2005-2009. The ECON Analysis projections were lower than actual consumption over the period FY 2005-2009. The Global Data forecast was almost in line with actual consumption, except for FY 2009 when the forecast was below the actual consumption. The Petrobangla forecast was nearly in line with actual consumption in FY2009.

The Wood Mackenzie and Technoconsult reports provided detailed methodologies on how their forecasts were derived, which will be discussed later in this report. The ECON Analysis and Global Data reports did not describe the methodologies used to develop their forecasts.

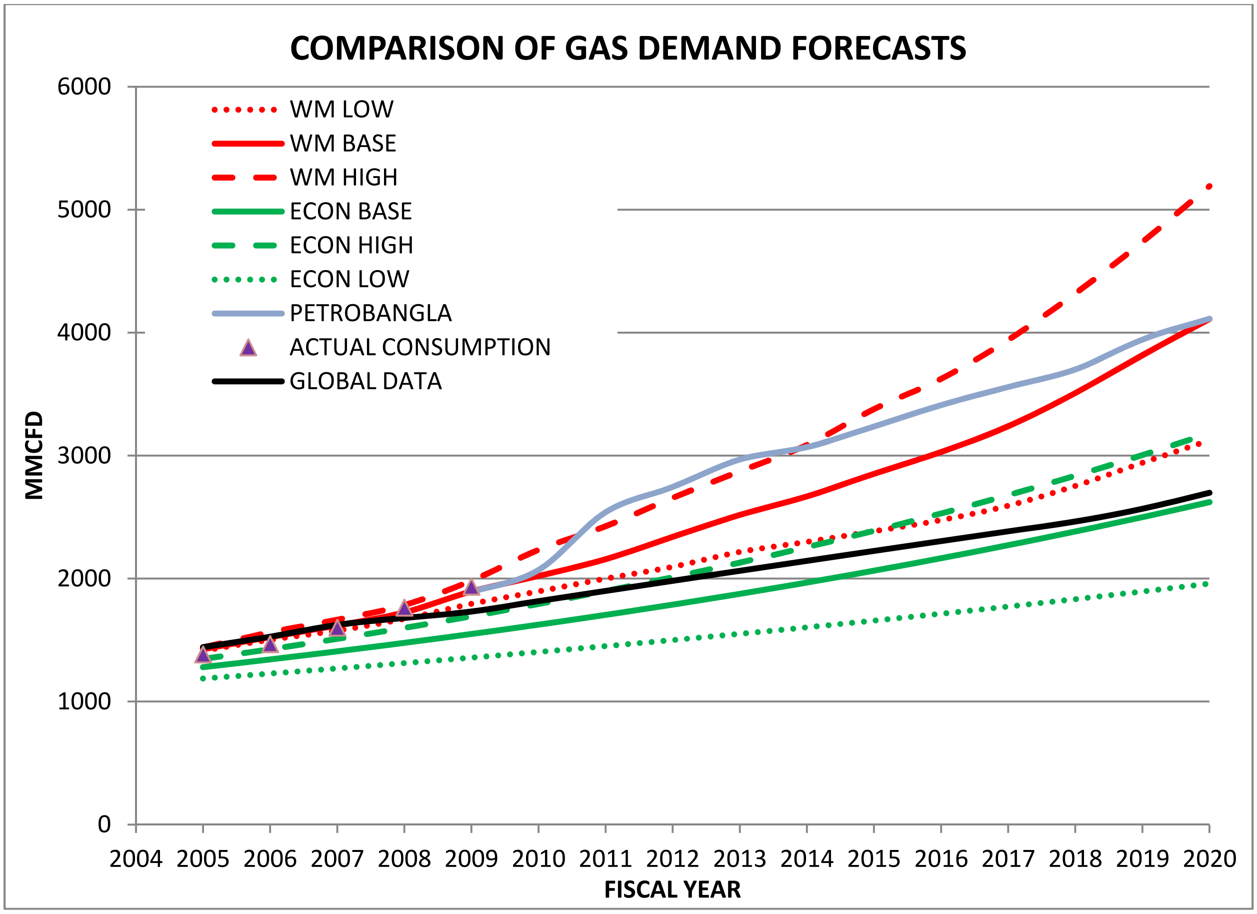


Figure 3-3 Comparison of Demand Forecasts

A major assumption driving the Wood Mackenzie forecast was that Bangladesh would introduce cost reflective tariffs to raise the price of natural gas to end users. These tariffs were assumed to come into effect between 2006 and 2010, lowering demand growth for natural gas by 2 to 3% per year. Another major assumption in this forecast was that new power generation plants would become much more efficient, requiring less gas to produce the same amount of electrical energy. The tariffs, as well as increases in generation efficiency have not been realized in Bangladesh. This implies that the Wood Mackenzie forecast of gas demand may be too low (especially in the power sector).

3.4 DETAILS OF PREVIOUS FORECASTS

This sub-section describes the methodologies used to develop the previous forecasts. A comparison of the demand forecasts by sector of each report is available in Appendix A.

3.4.1 Wood Mackenzie

The Wood Mackenzie report provides a detailed forecast of natural gas demand from FY 2004 to FY 2024. Their report was published in 2006. The report provides three different gas demand forecast scenarios, broken down into three sectors: power sector, fertiliser sector, and non-bulk sector. Case A is Wood Mackenzie's low growth forecast, Case B is their base case forecast, and case C is their high growth forecast.

3.4.1.1 Total Gas Demand Forecast

Case A: Figure 3-4 shows Wood Mackenzie's total low growth gas demand forecast by sector. In this scenario total demand is forecast to grow from 1,362 MMCF per day in FY 2004 to 4,005 MMCF per day in FY 2024. That is an overall growth of 194% and a CAGR of 5.5% per year. Demand is forecast to increase by 2.6 BCF per day by FY 2024. Figure 3-5 shows the actual shares of gas demand by sector in FY 2004 and a forecast of shares by sector in FY 2024. The power and non-bulk sectors constitute the bulk of the demand as well as the growth in demand. Demand in the power and non-bulk sectors are forecast to be 57% and 38% of total demand respectively in FY 2024. Demand in the fertiliser sector is forecast to remain almost unchanged. Due to the large growth in the power and non-bulk sectors, the fertiliser sector's share of total demand drops from 19% in FY 2004 to 5% in FY 2024 as shown in Figure 3-5.

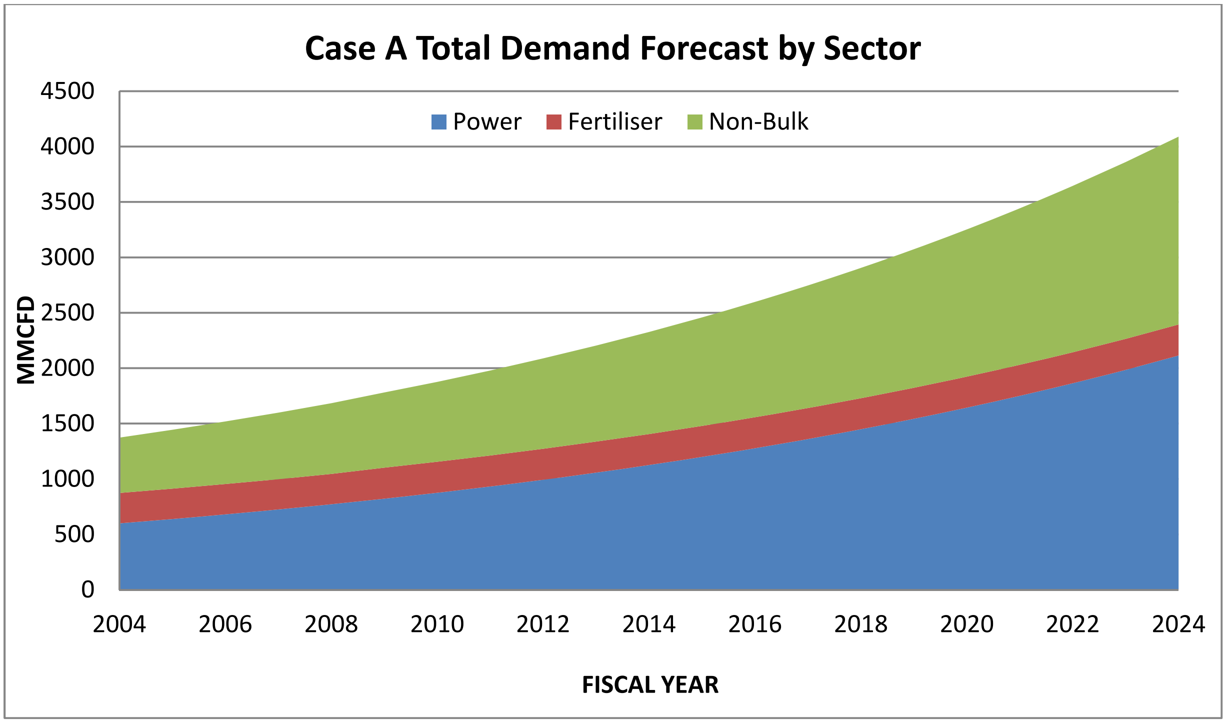


Figure 3-4 Low Growth Total Gas Demand Forecast by Sector[5]

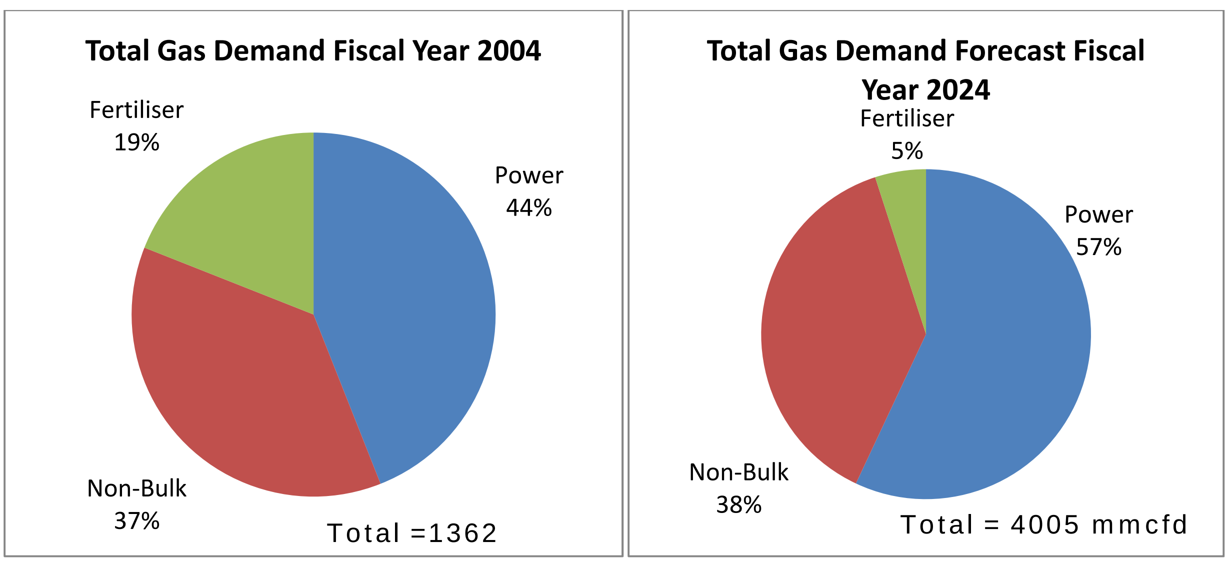


Figure 3-5 Comparison of Gas Demand by Sector (Low Growth)

[5] Source: Wood Mackenzie, 2006

Case B: Figure 3-6 shows Wood Mackenzie's base case demand forecast by sector. In this scenario total gas demand grows from 1,362 MMCF per day in FY 2004 to 5,606 MMCF per day in FY 2024. This represents an overall growth of 312% and a CAGR of 7.3%. Gas demand is forecast to increase by 4.2 BCF per day by FY 2024. Gas demand in the power and non-bulk sectors is forecast to increase considerably in this scenario at a CAGR of 8.7% and 7.7%, respectively. Demand in the fertiliser sector grows only slightly.

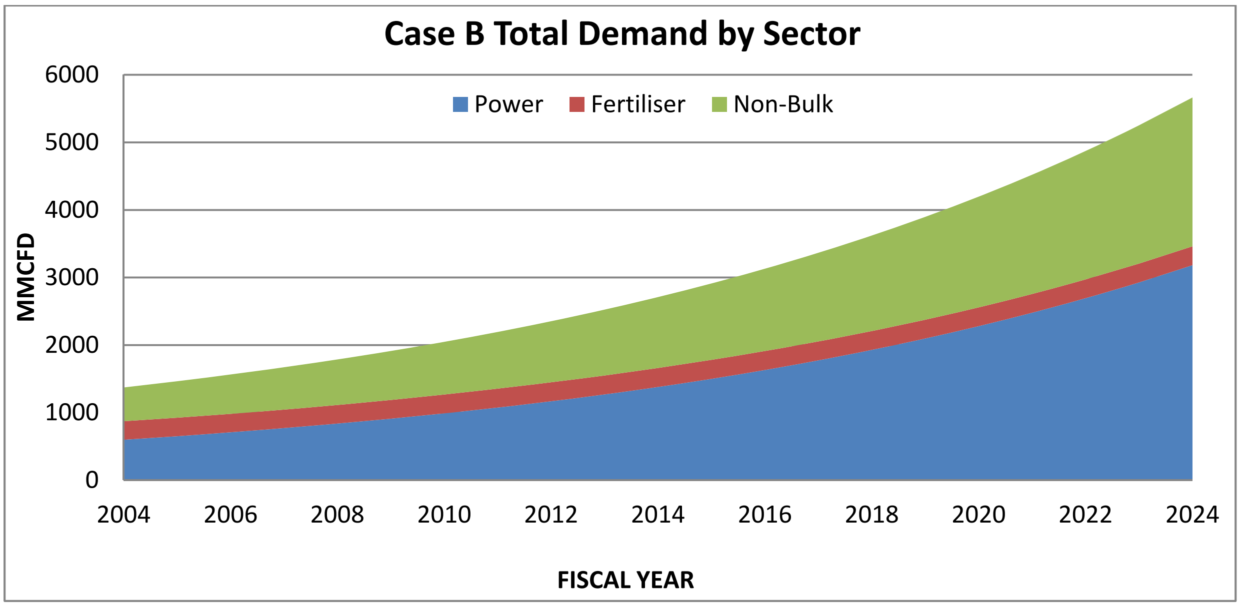
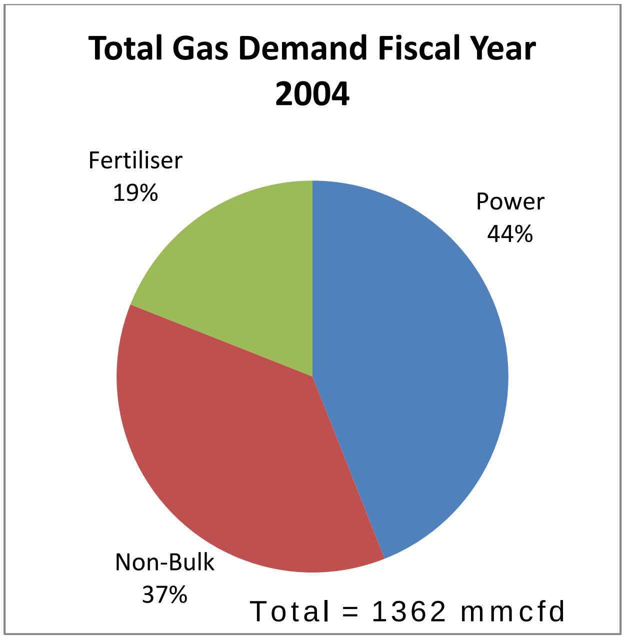


Figure 3-6 Base Case Total Gas Demand Forecast by Sector[6]

Figure 3-7 shows shares of actual gas demand in FY 2004 by sector as well as a forecast of shares in FY 2024. The power sector's share of total demand grows from 44% in FY 2004 to 57% in FY 2024. The fertiliser sector's share drops from 19% to 5% over the same time period. The non-bulk sector's share of total demand remains almost unchanged.

[6] Source: Wood Mackenzie, 2006



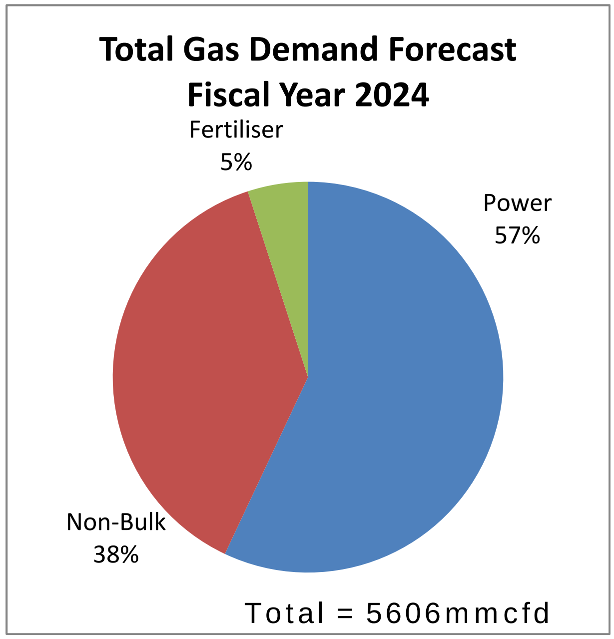


Figure 3-7 Comparison of Gas Demand by Sector (Base Case)[7]

Case C:

Figure 3-8 shows Wood Mackenzie's high growth demand forecast by sector. In this scenario, total demand rises from 1,362 MMCF per day in FY 2004 to 7,441 MMCF per day in FY 2024. This represents an overall growth of 546% and a CAGR of 8.9%. Gas demand is forecast to increase by 6.1 BCF per day by FY 2024. Demand rises significantly in both the Non-Bulk and power sectors, while rising by only a small amount in the fertiliser sector.

[7] Source: Wood Mackenzie, 2006

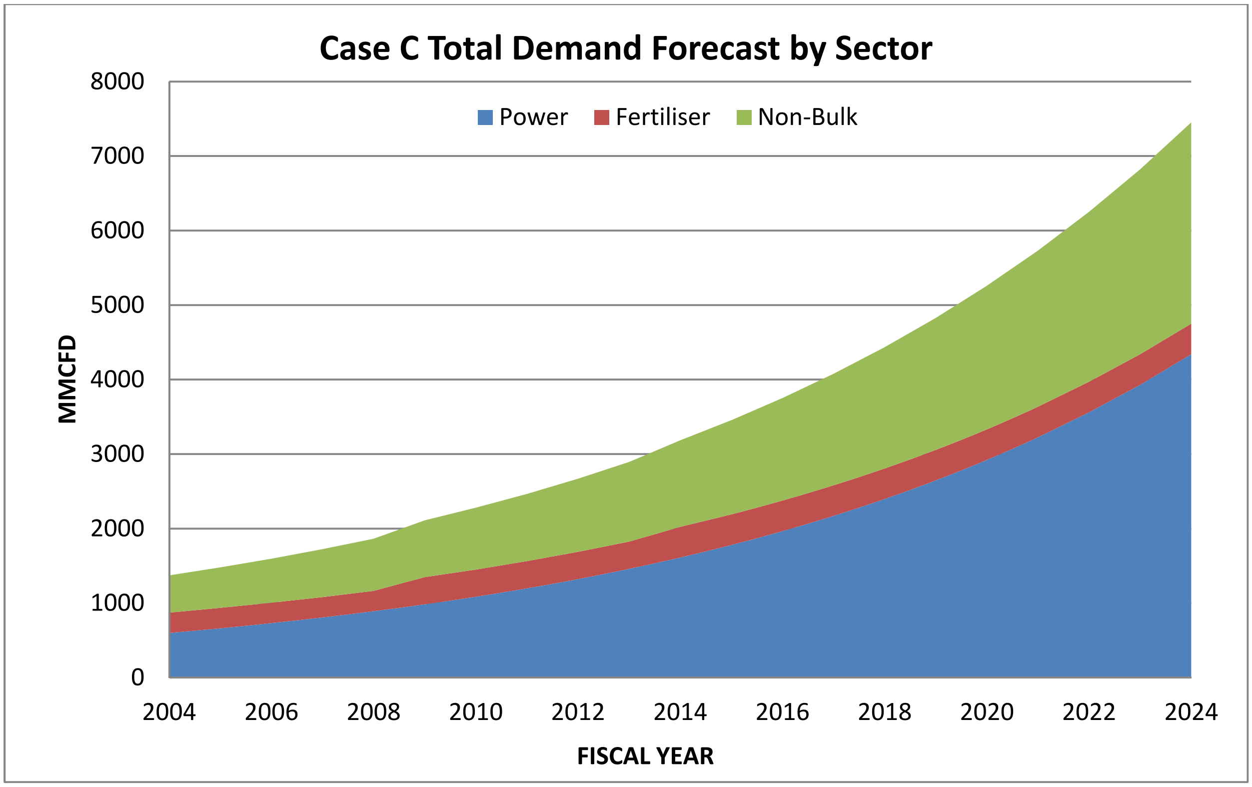


Figure 3-8 High Growth Total Gas Demand by Sector[8]

Figure 3-9 shows the shares of total gas demand by sector in FY 2004 and the forecast of gas demand shares by sector in FY 2024. The share of demand in the fertiliser sector drops considerably while the power sector's share of total gas demand increases by 14%. The non-bulk sector's share of total gas demand remains almost constant.

[8] Source: Wood Mackenzie, 2006

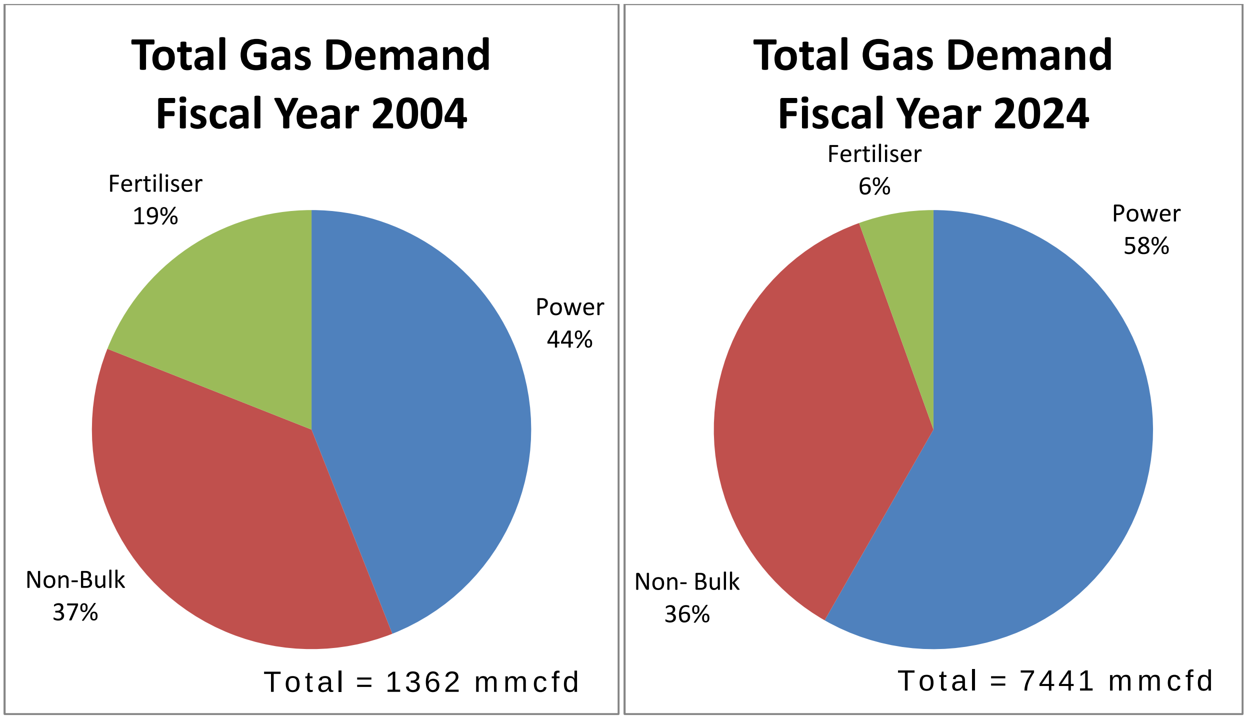


Figure 3-9 Comparison of Gas Demand by Sector (High Growth)[9]

The next subsection provides details of the gas demand forecasts for each of the three sectors.

3.4.1.2 Power Sector Demand

The power sector is the largest consumer of natural gas in Bangladesh. Wood Mackenzie forecasts power sector gas demand to rise significantly by FY 2024. Figure 3-10 represents the base, high growth, and low growth demand forecasts for the power sector. Gas demand in the power sector in FY 2024 is forecast to range between 2.1 and 4.3 BCF per day.

[9] Source: Wood Mackenzie, 2006

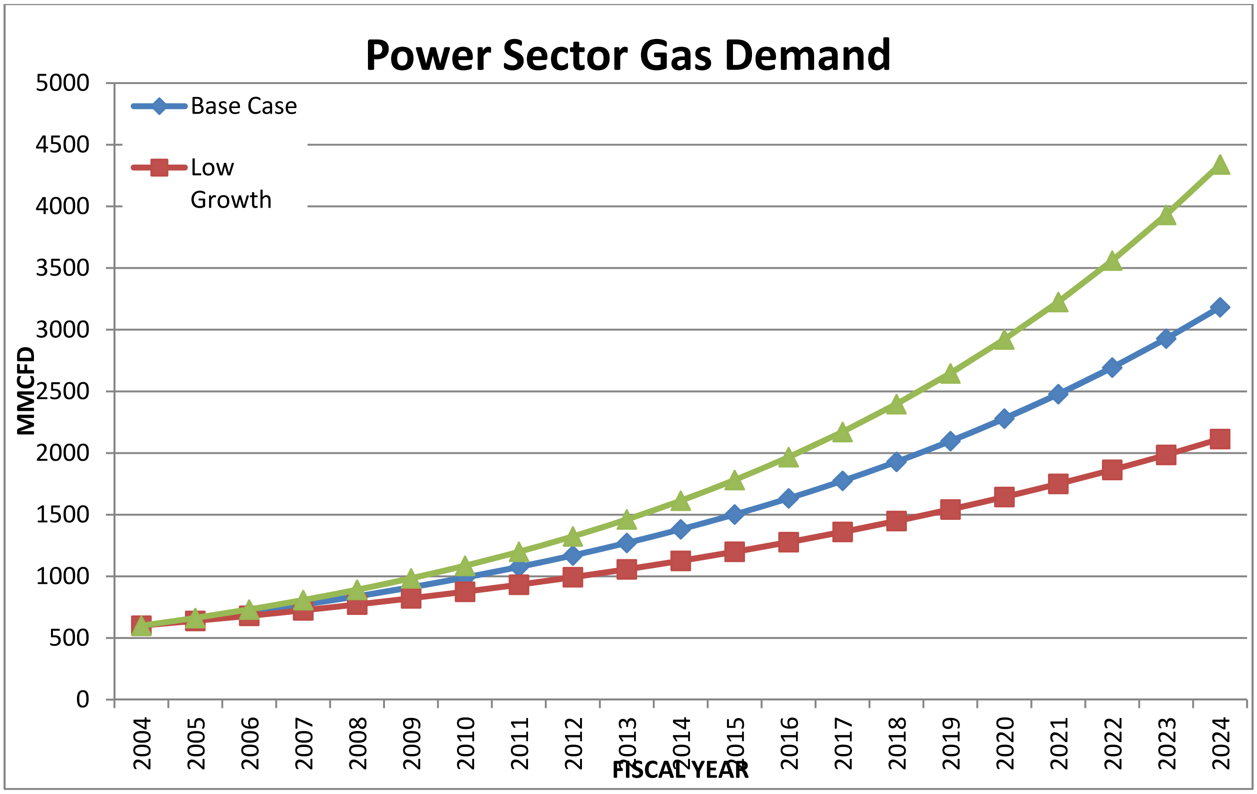


Figure 3-10 Power Sector Gas Demand Forecast[10]

Wood Mackenzie prepared forecasts of electricity load. The forecast of electricity load was carried out by conducting a regression analysis to establish the relationship between historic GDP and electrical energy load. The regression produced an r-squared value of over 99% indicating an extremely strong relationship between GDP and electrical energy load. The regression indicates that electricity load will grow by 1.5 times the GDP growth rate.

The gas demand forecasts in the power sector are based on three different GDP growth scenarios: Case A, Case B, and Case C (Figure 3-11). Each scenario makes different assumptions on how GDP will grow in Bangladesh.

- **Case A (Low Growth):** This scenario represents the recent trend in GDP growth in Bangladesh. It assumes that GDP will continue to grow at the most recent rate. In this case real GDP[11] will grow at 5.5% per annum to FY 2020 after which it is forecast to decline slightly to 5.3% through FY 2024.

[10] Source: Wood Mackenzie, 2006
[11] Real GDP refers to GDP corrected for inflation.

- **Case B (Base):** GDP growth is assumed to be stimulated by the Government reduction of poverty. In this scenario real GDP growth rises to 7% in FY 2010, peaks at 8% in FY 2015, falls to 6.5% by FY 2021 and remains at this level to FY 2024.
- **Case C (High Growth):** This scenario represents a high level of economic development and Real GDP growth. Under this case real GDP grows to 7% in FY 2005 and continues upward peaking at 9% in FY 2014. GDP then declines gradually to 7% by FY 2024.

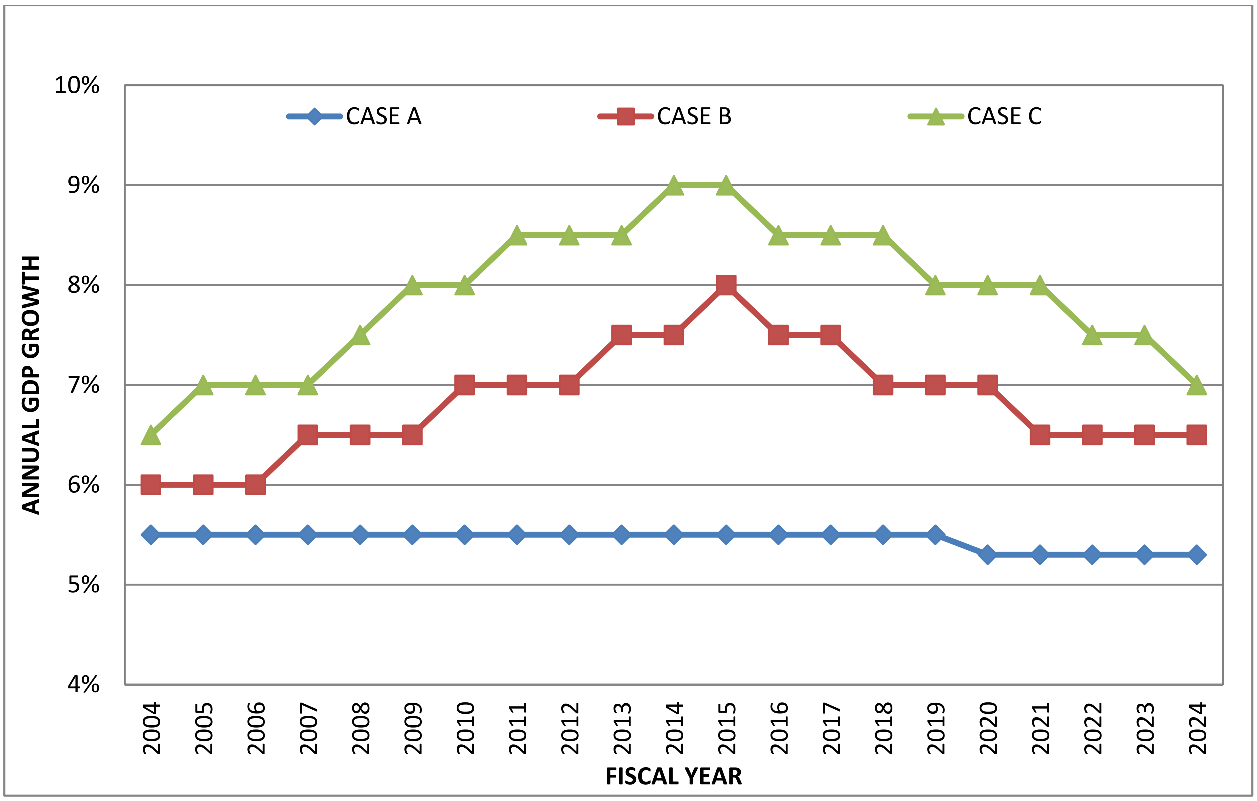


Figure 3-11 Representation of the Three Different GDP Growth Scenarios[12]

Electricity load is also affected by natural gas tariff reform in this forecast. Wood Mackenzie has assumed that a tariff reform would take effect in FY 2005-2010 increasing natural gas prices to competitive world prices. This increase is forecast to lower electricity growth rates by 2-3% per year over the five year period, after which the relationship between GDP and electricity load is predicted to return to its historical norm.

[12] Source: Wood Mackenzie, 2006

3.4.1.3 Non-Bulk Sector Demand

Wood Mackenzie derived demand forecasts for this sector by considering several franchise areas.[13] Within each franchise area a demand forecast was derived for the particular industries involved in the non-bulk sector. The non-bulk sector gas demand is expected to rise significantly in the future as shown in Table 3-3.

Table 3-3 Compound Annual Growth Rates by Franchise Area[14]

		CASE		
Franchise Area		A	B	C
Titas	Industrial	6.9%	8.8%	10.2%
	Captive	4.7%	5.6%	6.4%
	Residential	5.9%	7.4%	8.5%
	Commercial	1.6%	2.6%	4.2%
	CNG	10%	11%	12%
Bahkrabad	Industrial	8.1%	8.8%	9.5%
	Captive	5.6%	7%	8%
	Residential	5.6%	7%	8.1%
	Commercial	2.8%	3.5%	4.4%
	CNG	11%	12.2%	13.2%
Jalalabad	Industrial	11%	12.%	12.5%
	Captive	5.6%	6.7%	7.6%
	Residential	4.4%	5.4%	6%
	Commercial	2.2%	2.4%	2.9%
	CNG	**NA**[15]	**NA**	**NA**
PGCL	Non-Bulk	16%	18%	20%
S & SW	Non-Bulk	6.3%	7.7%	8.8%
TOTAL NON-BULK SECTOR DEMAND				
	Case			
	A	B	C	
	6.3%	7.7%	8.8%	

[13] A franchise area can be thought of as a region of Bangladesh controlled by an individual distribution company.
[14] Source: Wood Mackenzie, 2006
[15] Due to the low level of expected demand for CNG in Jalalabad, no forecast was conducted. An upward adjustment has been made to the residential and commercial forecasts to compensate.

Figure 3-12 represents the low growth, base case, and high growth forecasts of gas demand in the Non-Bulk Sector. Forecasted demand in the non-bulk sector in FY 2024 ranges from 1.7 to 2.7 BCF per day.

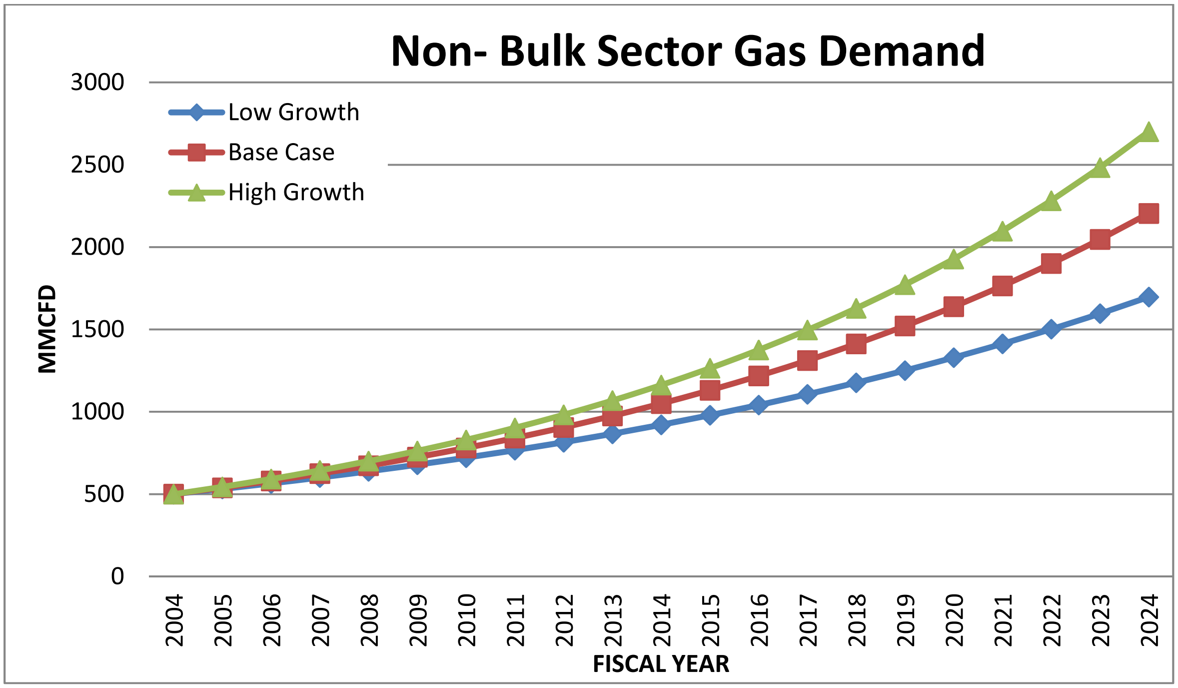


Figure 3-12 Non-Bulk Sector Gas Demand[16]

The industries included in the non-bulk sector are:

- Captive Power
- Commercial
- Residential
- CNG
- Industrial

The non-bulk sector demand forecast was derived based on the three GDP growth assumptions outlined above, and divided on a franchise area basis. Regression analyses were conducted to ascertain the strength of the relationship between GDP growth and natural gas demand for each industry and franchise area.

[16] Source: Wood Mackenzie, 2006

Captive power refers to power generation used by industry for their own consumption, that is not connected to the overall power grid. The captive power demand forecast was based on the assumption that power reliability will continue to be an issue in Bangladesh into the future. Without reliable power sources the need for captive power generation will continue to grow at a significant rate.

The demand in the CNG sector is based on the number of vehicles converted to CNG, which depends on whether consumers consider CNG as a good alternative to gasoline powered vehicles. The CNG sector is in the early stages of development in Bangladesh, with roughly 40,000 vehicles converted to CNG in FY 2004. The potential for CNG demand is between 55 and 80 MMCF per day by FY 2024, with the majority of demand concentrated in the greater Dhaka area.

3.4.1.4 Fertiliser Sector Demand

Bangladesh is an agricultural society with over 45% of its labor force employed in the agricultural sector.[17] This large segment of the economy drives the demand for fertiliser. Urea fertiliser is manufactured at seven urea plants in Bangladesh which produce around three million tons of urea per year.[18] Natural gas is used as a feedstock in the production of urea.

Table 3-4 shows the results of Wood Mackenzie's demand forecast for the fertiliser sector. Gas demand in the fertiliser sector was predicted to grow only very slightly by FY 2024.

Table 3-4- Gas Demand Forecast in Fertiliser Sector

Case	2004 Gas Demand (mmcfd)	2025 Gas Demand (mmcfd)	CAGR
A & B	274	280	0.1%
C	274	410	2.0%

[17] Source: The World Fact Book, 2010
[18] Source: Wood Mackenzie, 2006

The forecast for demand in the fertiliser sector was derived by estimating the demand for urea in Bangladesh as well as the expansion of urea plant capacity. To produce the gas demand forecast a plant by plant analysis was conducted. Wood Mackenzie derived three cases based on several assumptions. Cases A & B concluded that new urea plants would generate a negative net present value (NPV). Due to this fact no new urea plants would be built in Bangladesh. Gas demand in Cases A & B would increase moderately by FY 2024 to include expansions in the Chittagong facility.

- **Case A & B Assumptions:**
  - Notional ex-plant realized price of urea is US$ 165/ton.
  - Current gas price to the fertiliser sector is US$1.0/mmbtu.
  - A real discount rate of 10%
  - No new Greenfield Urea plants are built
- **Case C Assumptions:** This scenario takes into consideration the addition of two new urea plants in Bangladesh. The following are assumptions based on this scenario.
  - New Tata Urea plant will be commissioned by 2009.
  - Shahjalal factory is replaced.

In case C it was assumed that the economics alone would not deter the expansion of domestic production of urea. The logic here is that new urea facilities would create increased domestic demand for gas. This will in turn provide a signal to upstream suppliers (especially IOCs) that any future gas discoveries could be monetized in Bangladesh. In this way, it could be a positive step towards stimulating domestic exploration and production in the gas sector.[19]

3.4.2 Petrobangla

Technoconsult's report, published in 2009 was an analysis of Petrobangla's demand forecast. Petrobangla's forecast provides gas demand projections from FY 2009 to FY 2020. This report provides a total demand forecast as well as forecasts of gas demand in the power, fertiliser, captive power, and non-bulk sectors. Petrobangla's forecast can best be described as a

[19] Source: Wood Mackenzie, 2006

constrained demand forecast as growth rates have been adjusted downwards due to supply constraints. Petrobangla has not included demand that it is unable or does not intend to supply.[20]

3.4.2.1 Total Gas Demand

Figure 3-13 shows Petrobangla's total gas demand forecast to FY 2020 by sector. Total gas demand is forecast to rise from 1,890 MMCF per day in FY 2009 to 4,115 MMCF per day in FY 2020. This represents a CAGR of 7.3%. Gas demand is forecast to increase by 2.2 BCF per day by FY 2020.

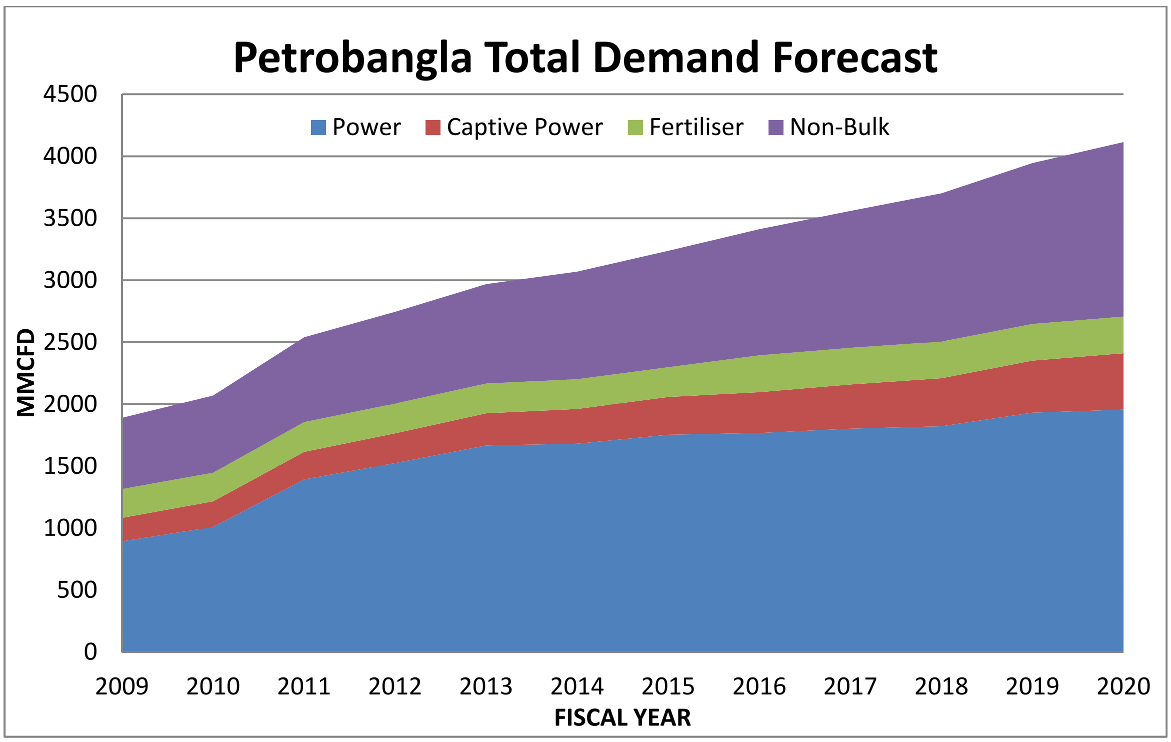


Figure 3-13 Total Gas Demand by Sector[21]

Figure 3-14 shows the actual distribution of gas demand by sector in FY 2009. The power sector is the largest consumer of natural gas in Bangladesh (47% of total demand), followed by the non-bulk sector (31%).

[20] Source: Technoconsult, 2009
[21] Source: Technoconsult, 2009

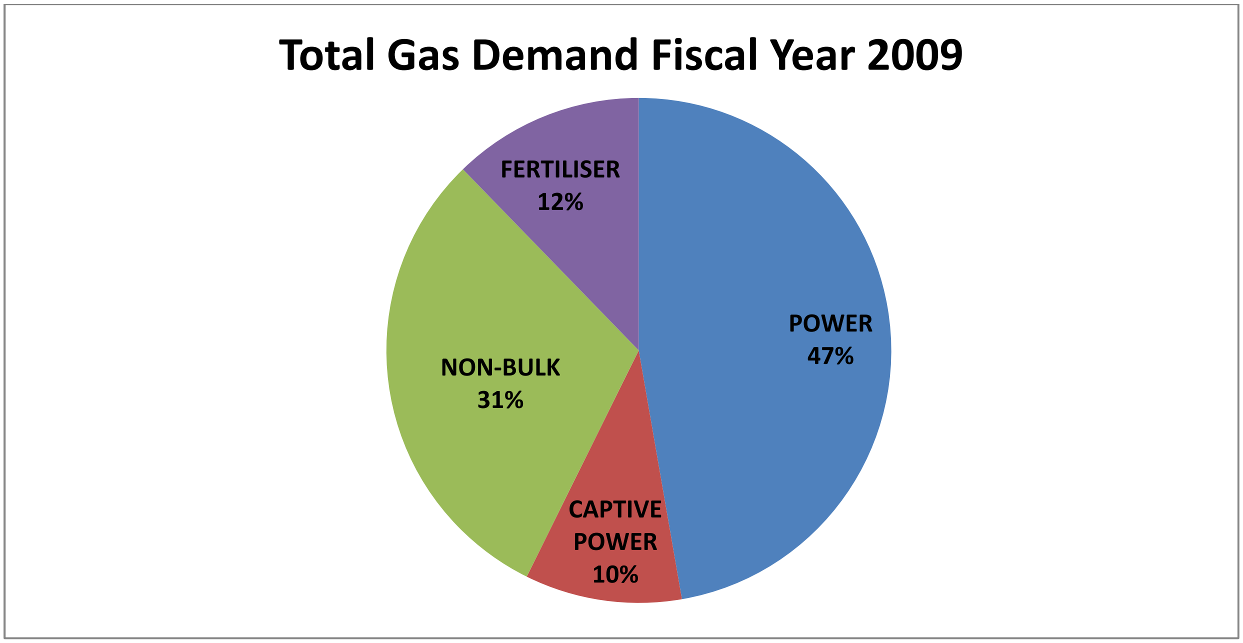


Figure 3-14 Distribution of Gas Demand by Sector FY 2009[22]

Figure 3-15 represents the forecasted distribution of natural gas by sector in FY 2020. The power sector is forecast to be the largest consumer of natural gas in Bangladesh in FY 2020 (48%) followed by the non-bulk sector (34%).

[22] Technoconsult, 2009

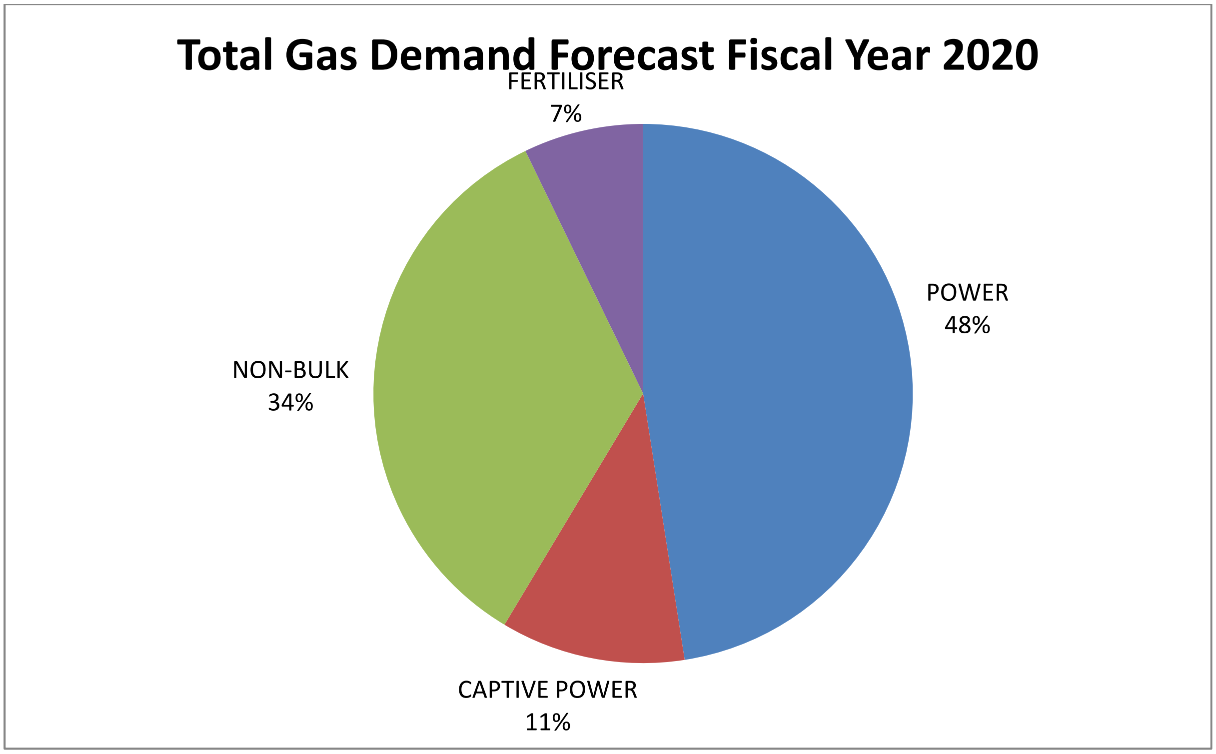


Figure 3-15 FY 2020 Sector Gas Demand Share Forecast[23]

3.4.2.2 Power Sector Demand

Figure 3-16 represents the demand forecast for natural gas in the power sector to FY 2020. Demand over this period was forecast to grow considerably from about 1,100 MMCF per day in FY 2009 to 2,450 MMCF per day in FY 2020. This represents a CAGR of 7.6%. The period FY 2009-2013 is forecast to be a period of high growth in gas demand for the power sector while the period FY 2013-2020 is forecasted to be a period of lower growth. The period of forecasted high growth in demand can be explained by the Bangladesh Power Development Board (BPDB) proposing to commission 5 new gas-fired power plants by FY 2012. The expansion plan of the BPDB is less ambitious after 2012, explaining the period of lower growth in gas demand for the power sector.

[23] Technoconsult, 2009

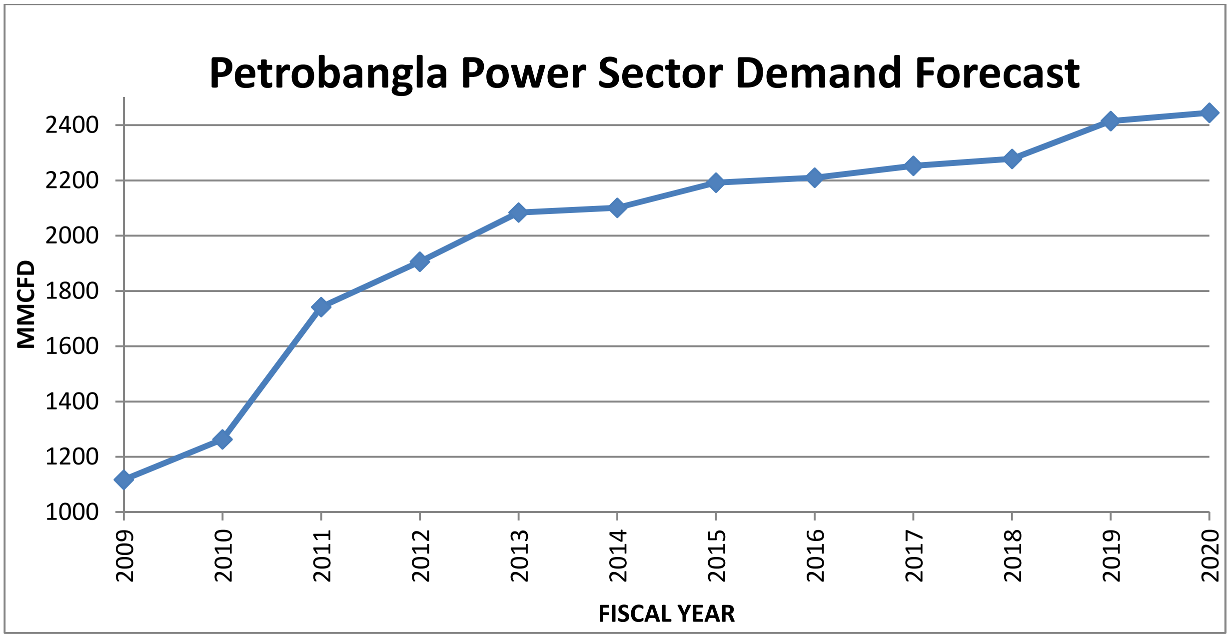


Figure 3-16 Forecast of Gas Demand in the Power Sector[24]

The power sector gas demand was derived using the 2005 Power Sector Master Plan, prepared by Nexant as a basis for the forecast. A regression analysis was used to show the strong correlation between electricity demand growth and GDP growth. This forecast assumed a constant real GDP growth rate of 5.5% per year. Further assumptions were made on the growth rate of the population as well as the power price to forecast electricity load. Electricity load was then compared to the power plant expansion plan to derive the total power sector gas demand forecast.

3.4.2.3 Captive Power Sector Demand

Figure 3-17 represents the forecasted demand in the captive power sector to FY 2020. In this forecast demand rises from about 240 MMCF per day in FY 2009 to 570 MMCF per day in FY 2020. This represents a CAGR of 8.2%

[24] Source: Technoconsult, 2009

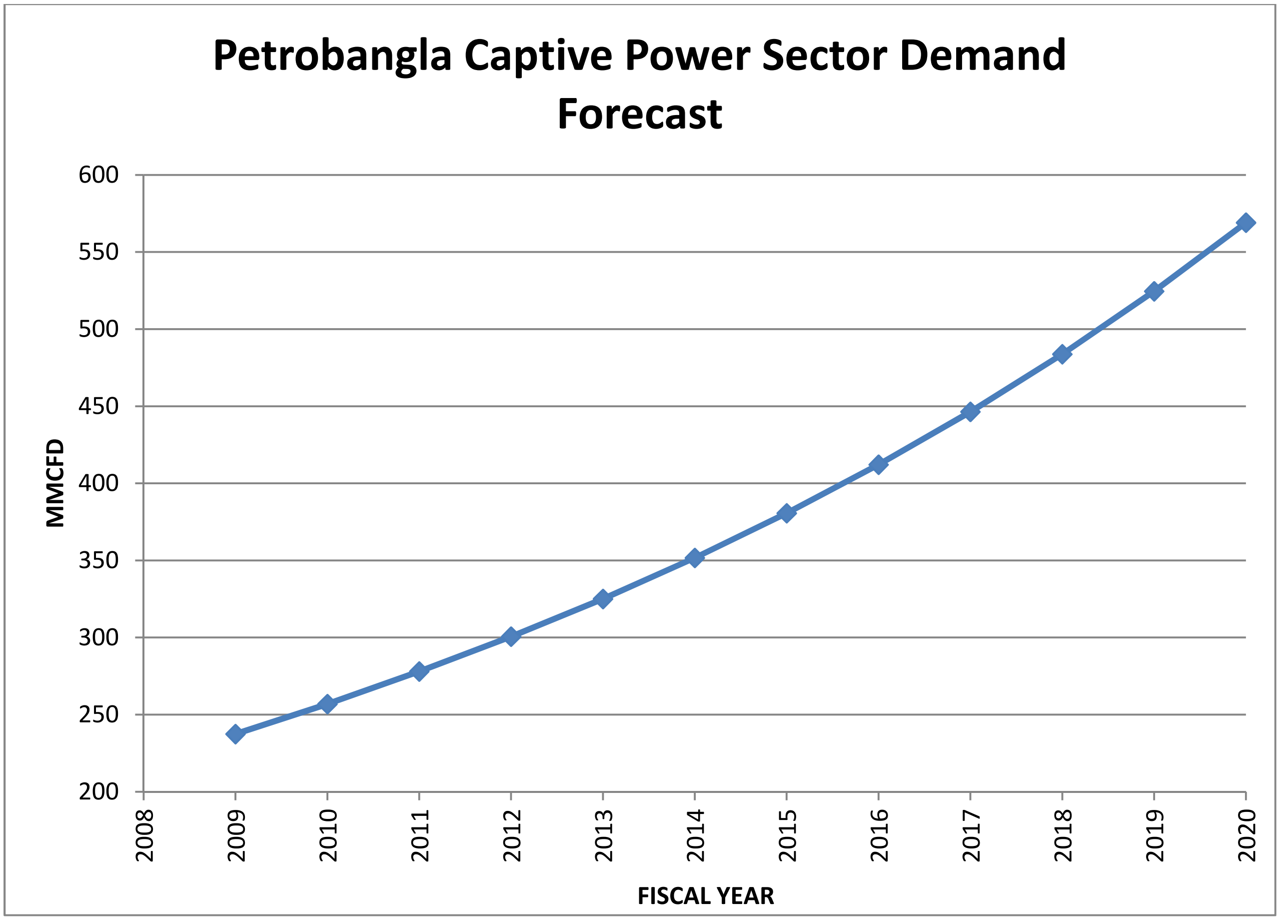


Figure 3-17 Forecast of Gas Demand in the Captive Power Sector[25]

Captive power refers to power generated by a firm for its own consumption. This power generation is independent from the overall power grid. The lack of a reliable energy supply in Bangladesh has driven the growth in demand for natural gas in the captive power sector. This is mostly due to Bangladesh's inability to currently supply 1,950 MW of grid power.[26] Petrobangla assumed a constant growth rate of roughly 8 % per year to forecast captive power gas demand.

3.4.2.4 Fertiliser Sector Demand

Figure 3-18 represents the gas demand in the fertiliser sector to FY 2020. This analysis shows relatively constant demand out to FY 2015. In FY 2016 a new Urea plant is planned to be

[25] Source: Technoconsult, 2009
[26] Source: Technoconsult, 2009

commissioned leading to an increase in gas demand of 70 MMCF per day. After the commissioning of the new facility, demand remains constant through FY 2020. No explanation is given to explain the small increase in gas demand between FY 2010 and FY 2011, however the data shows that the Jalalabad Gas Transmission and Distribution Systems (JGTDSL) increases its demand by 10 MMCF per day during this period.

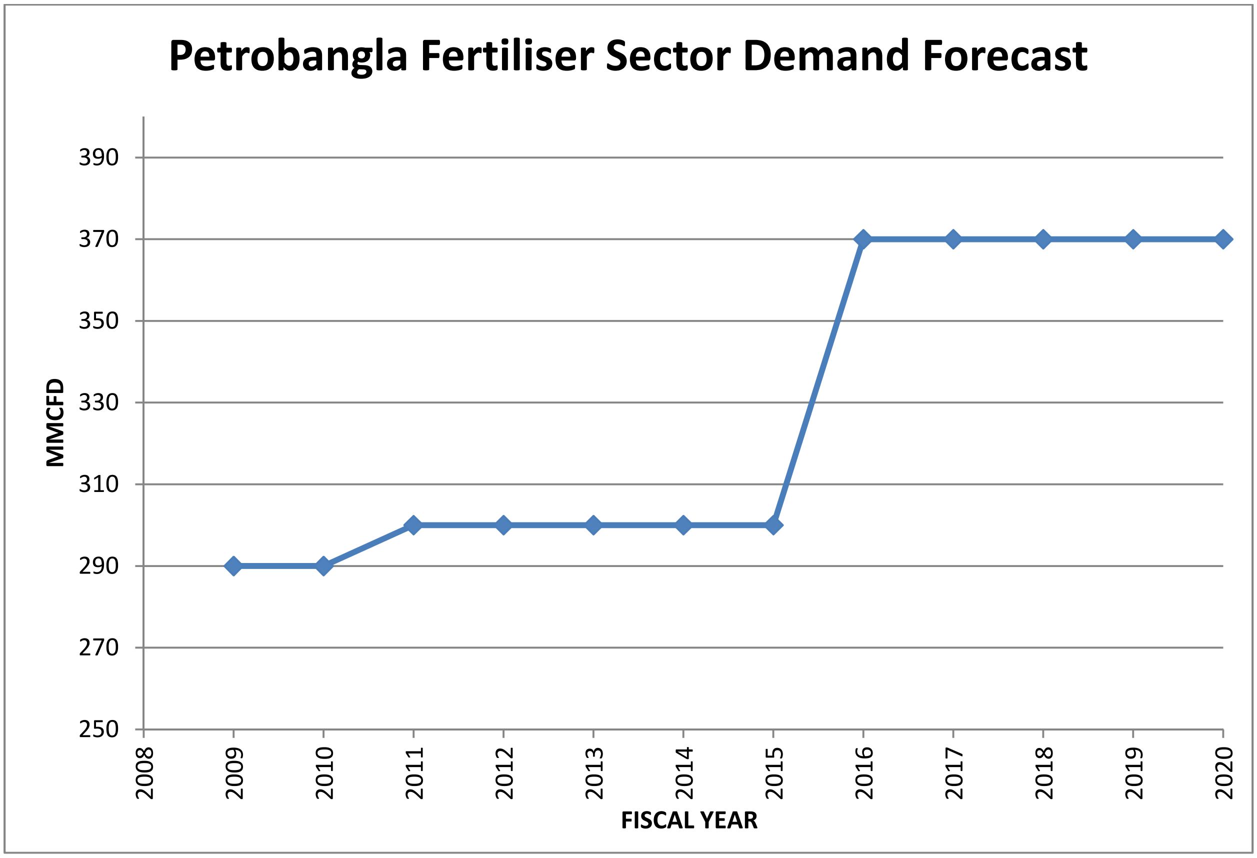


Figure 3-18 Forecast of Gas Demand in the Fertiliser Sector[27]

The Petrobangla forecast for demand in the fertiliser sector was derived by estimating the demand for urea in Bangladesh as well as the planned expansion of urea plant capacity. This involved a plant by plant study of the amount of natural gas consumed within each of the seven urea plants operating in Bangladesh.

[27] Source: Technoconsult,2009

3.4.2.5 Non- Bulk Sector Demand

Figure 3-19 shows the gas demand for the Non-Bulk Sector to FY 2020. Demand was predicted to grow significantly in this sector from roughly 700 MMCF per day in FY 2009 to 1,750 MMCF per day in FY 2020. This represents a CAGR of 8.7%.

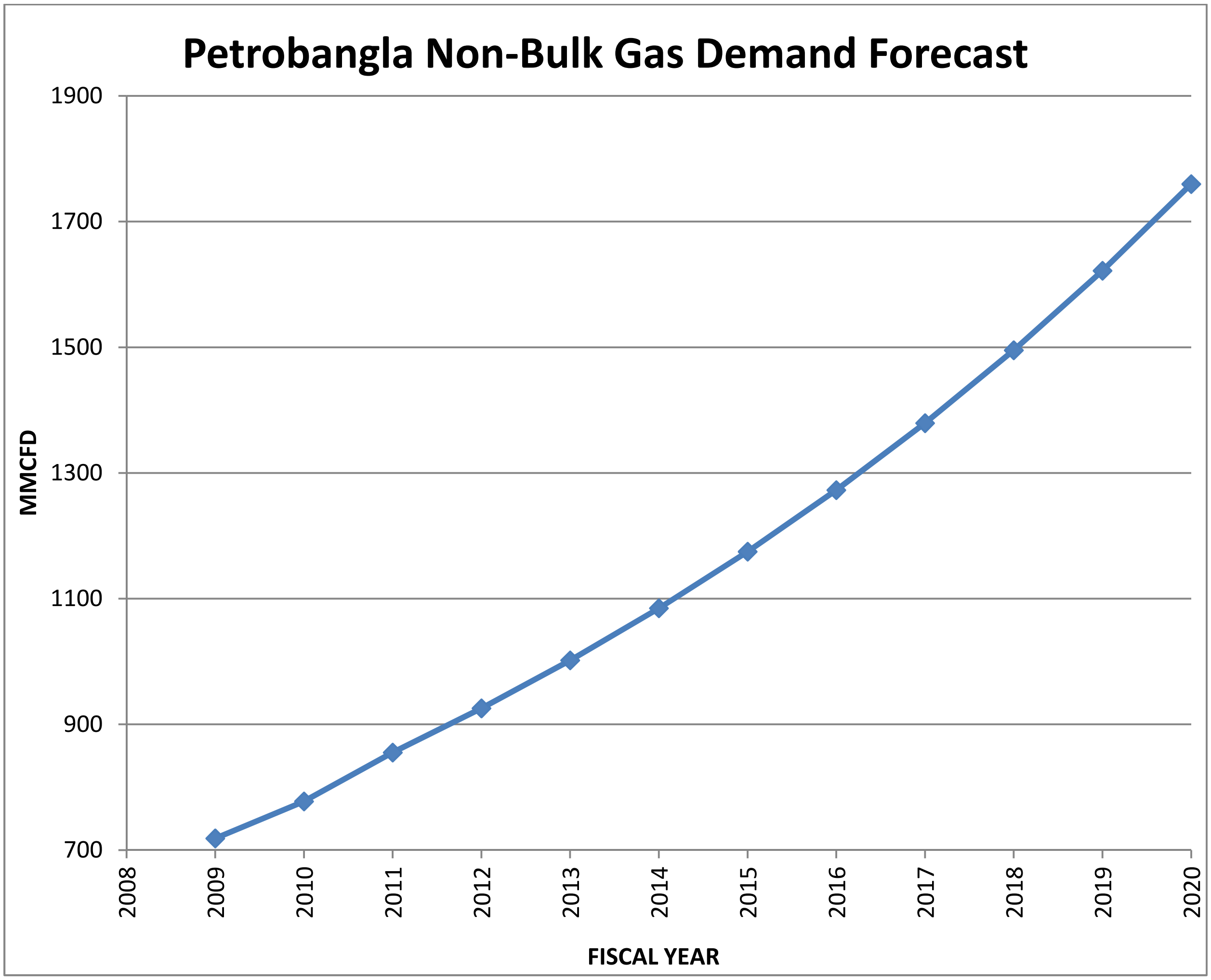


Figure 3-19 Forecast of Gas Demand in the Non-Bulk Sector[28]

The Non-Bulk demand forecast was derived using a constant annual growth rate of 8% for all distribution companies in Bangladesh, excluding Pashchimanchal Gas Company Ltd (PGCL). The growth rate in gas demand for PGCL was assumed to be 20%. No explanation was given

[28] Source: Technoconsult,2009

for why the growth rate in gas demand for PGCL was so much higher than the rest of the distribution companies.

3.4.3 ECON Analysis

In 2004, Econ Analysis prepared a forecast of gas demand in Bangladesh to the year 2030. It is divided by sectors which include Power, Fertiliser, Industry, Losses and Other. The report contains a base case, high growth, and low growth projections of gas demand. The results of the forecast for each sector are given in Table 3-5. The power sector is forecast to demand the most natural gas, and growth in power sector gas demand ranges between 4.4% and 6.5% per year.

Table 3-5 Gas Demand by Economic Sector[29]

Units: MMCF per day

Sector	Case	2000	2005	2010	2015	2020	2025	2030	CAGR 2000-2030
Power	Base Case	408	563	756	1044	1409	1831	2452	6.16%
	High Growth		563	923	1310	1882	2282	2736	6.55%
	Low Growth		543	640	818	1033	1219	1499	4.43%
Fertiliser	Base Case	233	247	304	306	282	282	230	0.00%
	High Growth		265	342	345	321	321	269	0.48%
	Low Growth		245	245	225	222	222	170	-1.05%
Industry	Base Case	125	213	314	410	509	615	717	6.00%
	High Growth		276	408	541	682	836	989	7.14%
	Low Growth		222	285	351	419	491	554	5.09%
Other	Base Case	100	158	218	280	360	462	591	6.10%
	High Growth		128	206	290	404	556	755	6.97%
	Low Growth		100	130	167	222	292	382	4.57%
Losses	Base Case	43	68	86	92	92	87	77	1.96%
	High Growth		76	101	113	117	114	105	3.02%
	Low Growth		58	65	67	66	62	54	0.76%
Total	Base Case	908	1249	1676	2132	2652	3277	4067	5.13%
	High Growth		1308	1980	2599	3406	4108	4854	5.75%
	Low Growth		1167	1364	1628	1963	2286	2660	3.65%

[29] Source: ECON Analysis, 2004.

Figure 3-20 shows the forecast of gas demand between FY 2005 and FY 2025. Demand in the base case rises from 1,249 MMCF per day in FY 2005 to 3,277 MMCF per day in FY 2025 representing a CAGR of 4.9%. Demand is forecast to grow by about 2 BCF per day by FY 2025. Demand in the high growth scenario rises from 1,308 MMCF per day to 4,108 MMCF per day with a CAGR of 5.9%. In this scenario, demand grows by about 2.8 BCF per day by 2025. Demand in the low growth scenario rises from 1,167 MMCF per day to 2,286 MMCF per day by FY 2025. This represents a CAGR of 3.4%.

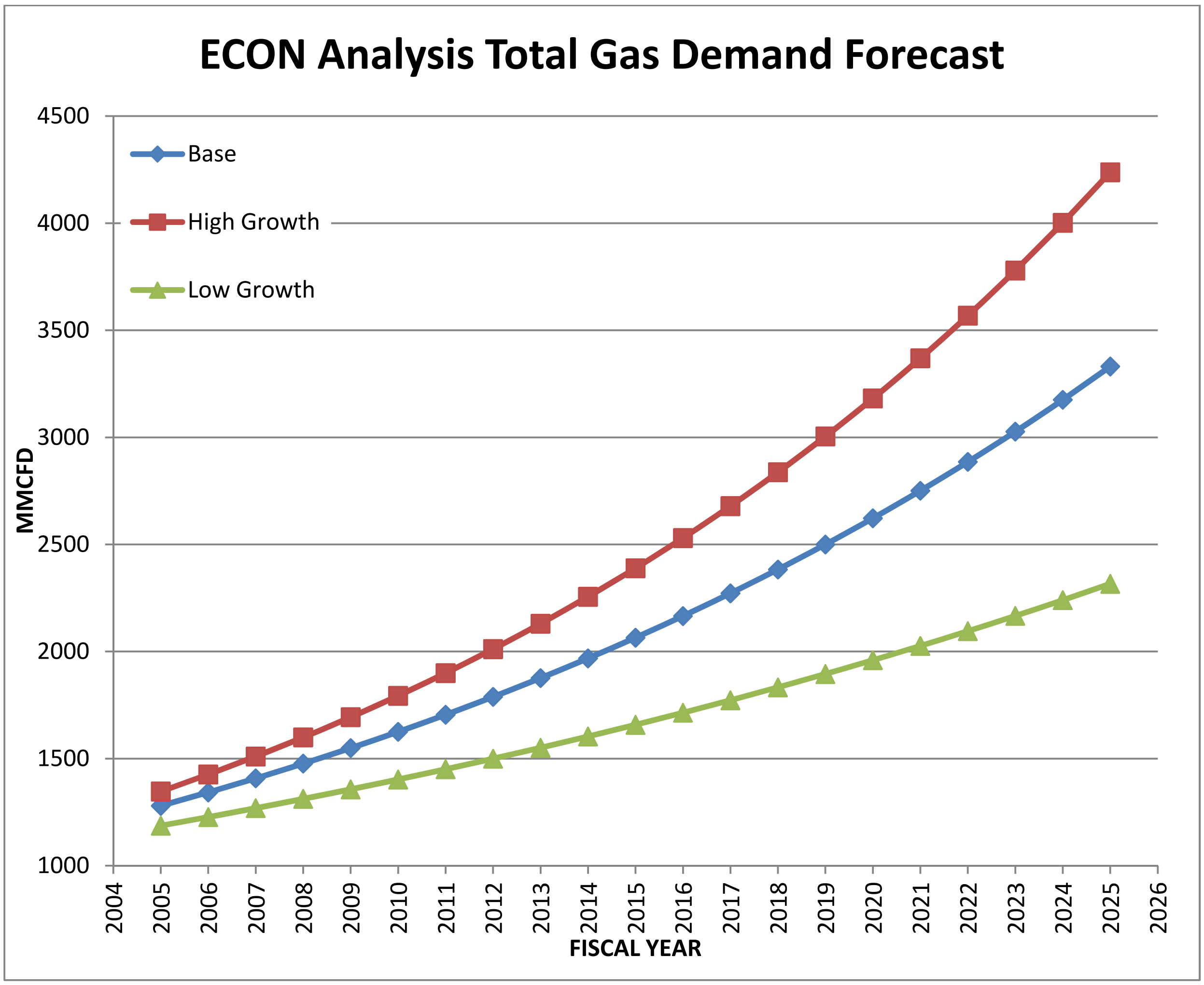


Figure 3-20 Bangladesh Total Gas Demand Forecast[30]

[30] Source: ECON Analysis, 2004

Figure 3-21 shows the share of total gas demand in Bangladesh by sector in FY 2000. The power sector is by far the largest consumer followed by the fertiliser sector.

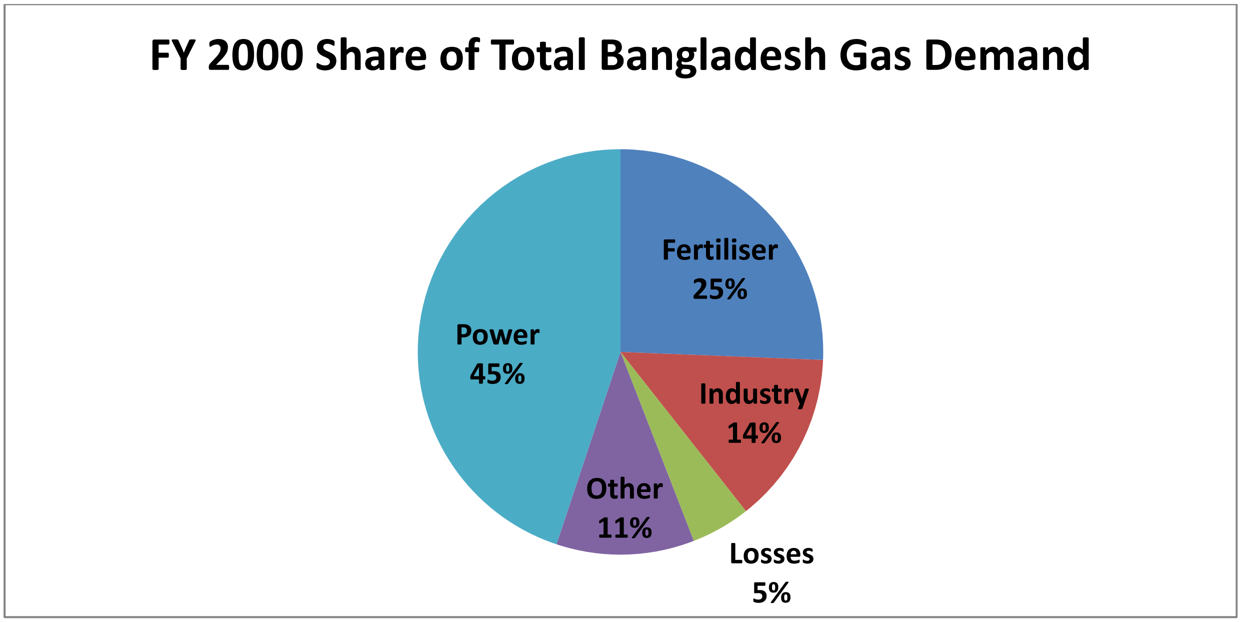


Figure 3-21 Share of Gas Demand by Economic Sector FY 2000[31]

Figure 3-22 represents the forecasted share of total gas demand in FY 2030. The power sector is forecast to remain the largest segment growing from 45% of total demand to 60% in FY 2030. Industry becomes the second largest user consuming 18% of total demand in FY 2030. The fertiliser sector's share of total demand shrinks because its growth is forecast to be small.

[31] Source: ECON Analysis, 2004

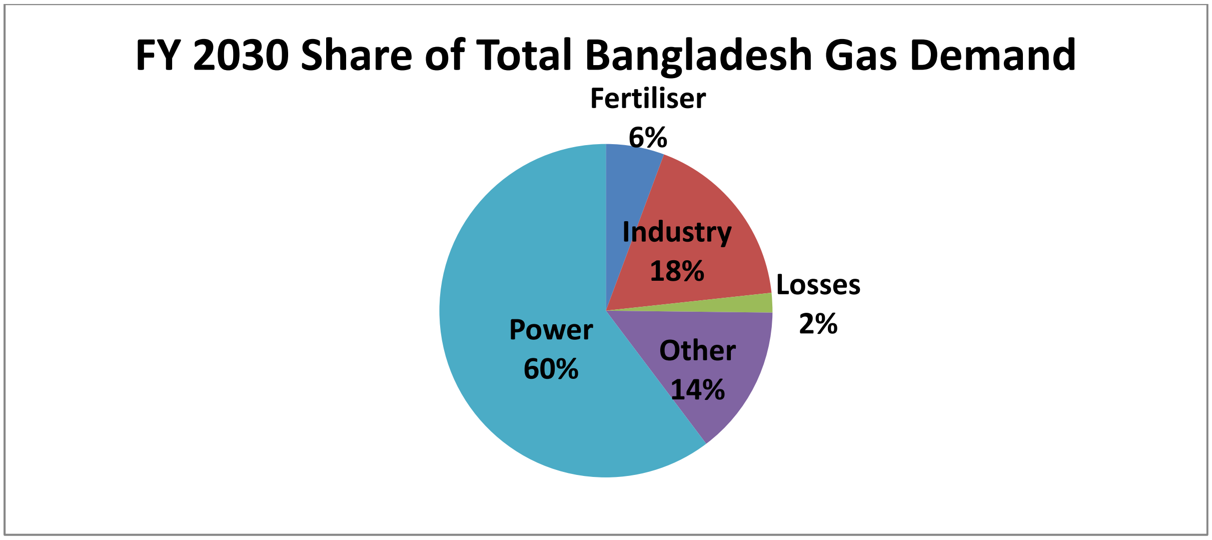


Figure 3-22 Share of Gas Demand by Economic Sector FY 2030[32]

3.4.4 Global Data Forecast

Global Data's forecast was conducted in 2010 as an economy wide forecast from FY 2005 to FY 2020. Their forecast includes actual historical data before 2010. Figure 3-23 shows Global Data's forecast to FY 2020. Demand is forecast to rise from 1,817 MMCF per day in FY 2010 to 2,698 MMCF per day in FY 2020. Demand is expected to increase over the period FY 2010-2020 at a CAGR of 4.0%.

[32] Source: ECON Analysis, 2004.

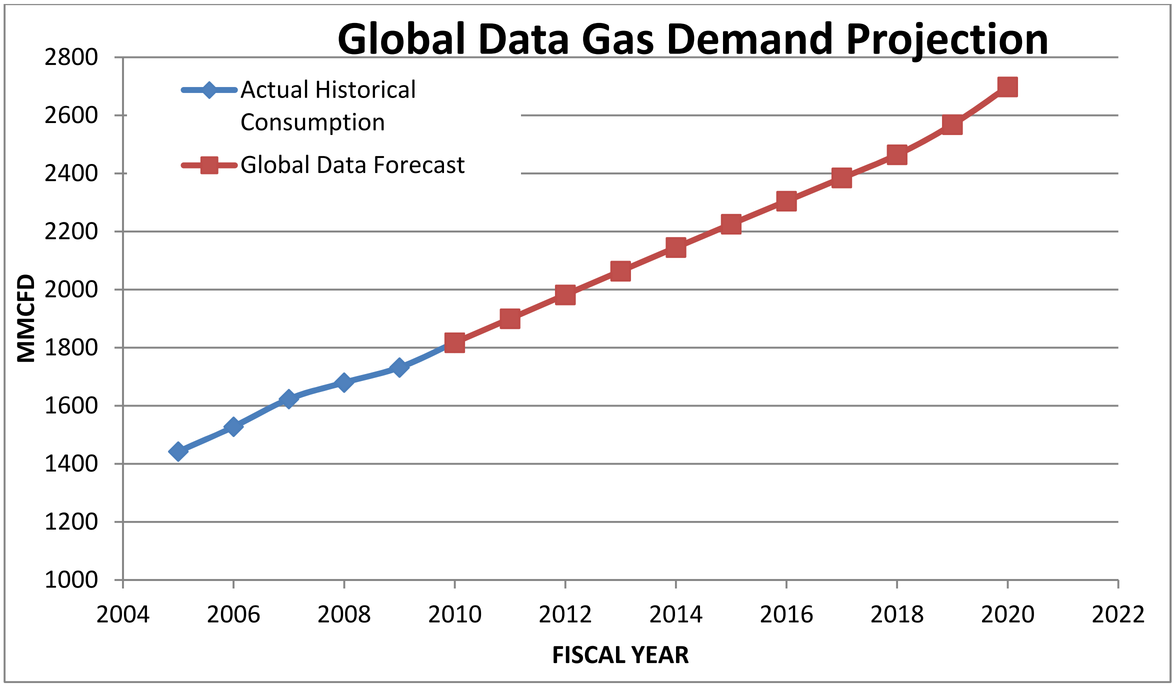


Figure 3-23 Total Gas Demand Forecast Bangladesh[33]

The Global Data Report did not describe the methodology used to derive their forecast.

3.5 NEW FORECAST SCENARIOS

The total gas demand in Bangladesh was about 1.9 BCF per day in fiscal year 2009. The average annual growth rate in historical gas demand over the previous decade was 9.2% or 10.0% per year (depending on the information source). The power sector is the largest consumer of natural gas. There have been shortages in the availability of natural gas. These shortages have resulted in frequent electrical load shedding. Demand growth was probably limited due to the lack of available gas.

We estimate that the average annual growth rate in the future demand for natural gas will be between 5.7% and 8.9% per year, with a base case estimate of 7.3% per year. These estimates imply that gas demand in FY 2025 will be between 5.1 and 8.3 BCF per day, with a base case estimate of 6.5 BCF per day. This represents a growth in demand of between 3.0 and 6.2 BCF

[33] Source: Global Data, 2010

per day, within 16 years from FY 2009. Since production from existing sources will go on decline in this time period, the amount of additional gas that must be supplied to the country is even larger than this. The next chapter of the report presents an analysis of the sources of supply that can meet this anticipated growing demand for natural gas in Bangladesh.

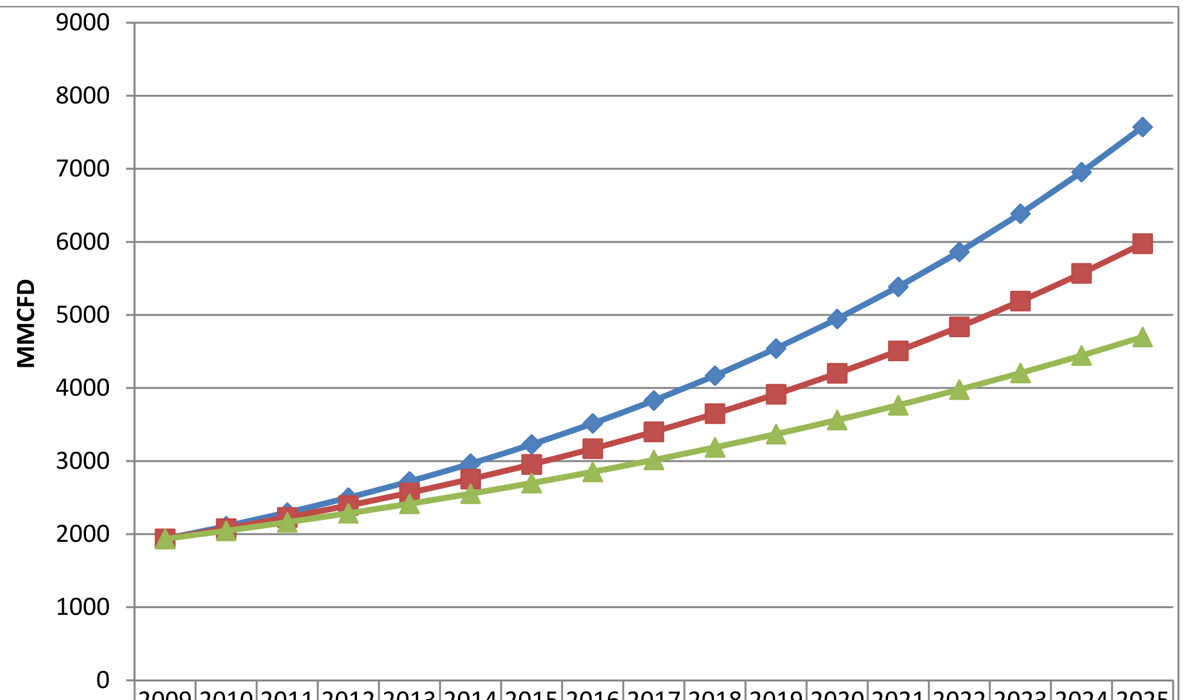
We have prepared three new gas demand scenarios for Bangladesh: a base case together with low and high scenarios that reflect a range of possible demands. Each scenario is based on actual consumption in FY 2009. Since the primary objective of this report was to analyze the total gas needs of the country a forecast by sector was not included in this analysis. Table 3-6 shows the growth rates used to develop the new scenario demand forecast.

Table 3-6 New Scenarios Forecast Growth Rates

NEW SCENARIOS GROWTH RATES			
Fiscal Year	Low Growth	Base Case	High Growth
2010	5.7%	7.3%	8.9%
2011	5.7%	7.3%	8.9%
2012	5.7%	7.3%	8.9%
2013	5.7%	7.3%	8.9%
2014	5.7%	7.3%	8.9%
2015	5.7%	7.3%	8.9%
2016	5.7%	7.3%	8.9%
2017	5.7%	7.3%	8.9%
2018	5.7%	7.3%	8.9%
2019	5.7%	7.3%	8.9%
2020	5.7%	7.3%	8.9%
2021	5.7%	7.3%	8.9%
2022	5.7%	7.3%	8.9%
2023	5.7%	7.3%	8.9%
2024	5.7%	7.3%	8.9%
2025	5.7%	7.3%	8.9%

Our base case forecast assumes a growth rate of 7.3%, somewhat lower than the actual average growth rate in gas demand over the previous decade, but the same as Petrobangla’s base case. We find the Petrobangla growth rate to be a good estimate for the base case. They have extensive experience with the gas sector in Bangladesh. It is reasonable that the growth in gas demand should be slower than it has been in the past, since historical growth was from a very low base. One would expect high initial growth rates from a low base in a developing economy. However, growth typically slows down after rapid initial development. Our high and low growth projections use growth rates of 8.9% and 5.7%, respectively. These growth rates are the same as Wood Mackenzie's high and low growth demand projections. Wood Mackenzie did a detailed sector by sector forecast of gas demand. We carefully reviewed their work, and found their growth rates to be reasonable. Since the Wood Mackenzie report was published five years before our report, we used the actual gas production in fiscal year 2009 as a starting point rather than 2009 rates that were forecast by Wood Mackenzie.

Figure 3-24 shows the new demand scenarios for Bangladesh. (The values from the chart are shown below the horizontal axis.)



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
High Growth	1935.	2107.	2295.	2499.	2722.	2964.	3228.	3515.	3828.	4169.	4540.	4944.	5384.	5863.	6385.	6953.	7572.
Base Case	1935.	2076.	2228.	2391.	2565.	2752.	2953.	3169.	3400.	3649.	3915.	4201.	4508.	4837.	5190.	5569.	5975.
Low Growth	1935.	2045.	2162.	2285.	2416.	2553.	2699.	2853.	3015.	3187.	3369.	3561.	3764.	3978.	4205.	4445.	4698.

Figure 3-24 New Bangladesh Gas Demand Forecast Scenarios

Natural gas demand in FY 2025 is forecast to be between 4.7 and 7.6 BCF per day. In our base case forecast demand grows from 1.9 BCF per day in FY 2009 to 6.0 BCF per day in FY 2025. The low growth projection forecasts demand to be 4.7 BCF per day in FY 2025, and the high growth projection forecasts demand to be 7.6 BCF per day in FY 2025. Demand for these three scenarios is forecast to increase above the FY 2009 level by between 2.8 and 5.6 BCF per day by FY 2025.

4 GAS INFRASTRUCTURE AND POTENTIAL ENERGY SUPPLY SOURCES

4.1 GAS TRANSMISSION AND MARKETING INFRASTRUCTURE

Gas transportation pipelines, shown in Figure 4-1, carry gas from the fields in Bangladesh to industrial and private customers that are located primarily in the eastern portion of the country. Natural gas is also used to generate electricity, which is then distributed throughout the country. In 2000 a multi-use bridge was completed over the Jamuna River to provide increased access to the western portions of Bangladesh. This access includes a 30-inch gas pipeline that has promoted additional pipeline systems in western Bangladesh. Some of these expansion projects include Nalka to the Baghabari Power Plant in 2001, with a 20-inch pipeline, three network integration projects between 2002 and 2006, and a pipeline to Dhaka in 2007. With predicted increasing demand for natural gas and electricity in Bangladesh, the pipeline system will continue to be important. The estimated total demand for natural gas in FY 2009 was about 707 BCF. The total delivered gas through the country's pipeline system for 2009 was approximately 685 BCF.

There are six companies that market and transport natural gas to different areas of the country, Titas Gas Transmission & Distribution Co. Ltd. (TGTDCL), Bakhrabad Gas Systems Ltd. (BGSL), Jalalabad Gas Transmission & Distribution Company Ltd. (JGTDSL) and Pashimanchal Gas Distribution Co. Ltd. (PGCL), Karnaphuli Gas Distribution Company Ltd. (KGDCL), and Sundarbans Gas Company Ltd (SGCL). SGCL is not distributing any gas as yet. It is a new company established for gas distribution in southwestern Bangladesh.

Titas Gas operates transmission and distribution lines totaling 11,496 kilometers and markets to thirty-one power plants and four fertilizer plants along with other industrial and private customers. Sales of natural gas in the fiscal year 2008-2009 were 474.8455 BCF.[34]

[34] Petrobangla.org.bd

Figure 4-1 Gas Transmission Network Map of Bangladesh

Bakhrabad markets gas to nine power plants and three fertilizer plants in addition to other industrial and private customers through its 6,246.62 kilometer pipeline network. Sales of natural gas in the fiscal year 2008-2009 were 101.6348 BCF.[35]

Jalalabad sold gas through its 2,960.21 kilometers pipeline system to nine power plants and one fertilizer plant, in addition to other industrial and private customers, amounting to 43.5471 BCF in fiscal year 2008-2009.[36]

Pashchimanchal sells gas to areas west of the Jamuna River with a current pipeline network of 970.22 kilometers. It sold 27.68 BCF of gas to customers in fiscal year 2008-2009[37].

Gas Transmission Co. Ltd. (GTCL) was established to centralize the construction and operation of high-pressure gas transmission pipelines.

4.2 EXISTING FIELDS

There are twenty-three discovered gas fields in Bangladesh that have an estimated total Proved plus Probable gas initially in place (GIIP) of 35.5 TCF. Recoverable reserves are estimated to be 24.3 TCF (1P) and 28.2 TCF (2P). Currently, seventeen gas fields are producing from 79 wells. Daily gas production is about 2,000 MMCF per day. Some of the fields have been producing since 1960. Cumulative production reported by Petrobangla as of December 2010 is 9.43 TCF. This means there is an estimated 18.77 TCF remaining reserves (2P). The gas reserves are summarized in Table 4-1.

Table 4-1 Gas Reserve Summary

Category	Gas Reserves, TCF
GIIP (Proven+ Probable)	35.50
Recoverable (Proven + Probable)	28.20
Cumulative Production (as of December 2010)	9.43
Net Recoverable	18.77

[35] Petrobangla.org.bd
[36] Petrobangla.org.bd
[37] Petrobangla.org.bd

The gas fields are operated by three national companies and four IOC companies. BGFCL is the operator of the Titas, Bakhrabad, Habiganj, Narsingdi, Kamta (currently non-producing), and Meghna gas fields. SGFL is the operator of the Sylhet, Kailashitila, Rashidpur, and Beani Bazar gas fields. BAPEX is the operator of Slada Nadi, Fenchuganj, and Shahbazpur gas fields. The fields that are operated by IOCs with PSCs are the Chevron operated Jalalabad, Moulavi Bazar, and Bibiyana gas fields, the Santos operated Sangu gas field, the Tullow operated Bangura gas field, and the Niko operated Feni (currently non-producing) gas field. There are three undeveloped gas fields, the Begumganj, the Semutang, and the Kutubdia gas fields. IOC operated fields make up 55% of the total production.

4.2.1 Field Production History

- The Chattak gas field began producing in 1959. The gas was supplied to the Assam Bengal Cement Factory.
- The Sylhet gas field began commercial production in 1960. The only consumer was the Fenchuganj Natural Gas Fertilizer Factory.
- The Titas gas field started producing in 1968.
- The Habiganj gas field started producing in 1969.
- The Kailastila gas field started producing in 1984.
- The Bakhrabad and Kamta gas fields started producing in 1985.
- The Feni gas field started producing during the 1991-1992 time period.
- Production from Chattak and Kamta was suspended in 1985 and 1998 as a result of excessive water production from several different wells.
- The first offshore gas field was the Cairn Energy Bangladesh Ltd. operated Sangu gas field which began producing in June of 1998.
- Currently gas is being produced from 17 fields that are operated by 3 national oil companies and 4 international oil companies (IOCs) under PSC and JVA.
- As of December 2010, the cumulative gas production is 9.43 TCF.
- Gas production increased substantially after 2000.

4.2.2 Petrobangla Owned Producing Gas Fields

4.2.2.1 Titas Gas Field, Block 12, BGFCL

The Titas gas field is within the Brahmanbaria area which is approximately 100 km northeast of Dhaka. It was discovered in 1962 following a seismic survey that was completed by the Pakistan Shell Oil Company. The field is an asymmetric anticline structure extending north and south approximately 19 km x 10 km, with a vertical closure of 500 meters. The field began producing in 1968 and cumulative production as of June 30, 2010 was 3,139 BCF. Recoverable reserves are 7,582 BCF and the remaining reserves are 4,514 BCF. Currently, sixteen wells have been drilled. The recent daily production rate was 450 MMCF per day from fifteen wells. There are seven vertical wells and nine directional wells with plans to drill two more wells in the future. The gas field has five glycol dehydration facilities each with a processing capacity of 60 MMCF per day. There are also six low-temperature separation type gas processing facilities. The gas is supplied to the Titas Gas Transmission & Distribution Company Ltd. (TGTDCL) and the Gas Transmission Company Limited (GTCL).

4.2.2.2 Bakhrabad Gas Field, Block 9, BGFCL

The Bakhrabad gas field is located at Muradnagar upazila in the Comilla area which is east of Dhaka. It was discovered in 1969 by the Pakistan Shell Company Ltd. (PSCO). The field was discovered in the same manner as the Titus and Habiganj gas fields. The first well was drilled to a depth of 2,838 meters based on the magnetic measurements taken by the Pakistan Petroleum Ltd. (PPL) in 1953 and a seismic survey conducted by Shell in 1968. The anticline structure has a long and thin symmetric shape, approximately 69 km x 10 km, facing in a NNW-SSE direction. Production began in 1984 and as of June 2010, the cumulative gas production was 704 BCF. Recoverable reserves are estimated to be 1,387 BCF and remaining reserves are 689 BCF. A total of eight wells have been drilled in two different areas of the field. There are four wells that have been shut-in because of water invasion. A plan is in place to stop the water invasion by completing remedial work in those wells. When all eight wells were producing, daily production rates reached 120 MMCF per day. Current production rates from the four producing wells are 33

MMCF per day. One well is a vertical well and the other seven wells are directional wells. The Bakhrabad gas field has four silica gel type gas processing plants. The gas is supplied to the transmission pipeline of the Bakhrabad Gas Systems, Ltd. (BGSL).

4.2.2.3 Habiganj Gas Field, Block 12, BGFCL

The Habiganj gas field is located in the Habiganj area which is approximately 100 km northeast of Dhaka. The structure of the gas field is at the north end of the Tripuran Baramura anticline structure in India. There is a main gas reservoir and an upper gas sandstone reservoir south of Sadr. In 1962, the PSCO conducted a seismic survey. In 1963, an exploratory development plan was initiated targeting the gas bearing sandstone reservoirs. The dimension of the structure is 12 km x 5 km, with a closure of 300 meters. Production began in 1968 and as of June 2010, the cumulative field production was 1,713 BCF. Recoverable reserves are 2,787 BCF and remaining reserves are 1,116 BCF. Of the eleven existing wells, nine are currently producing at a daily production rate of 250 MMCF per day. There are six glycol type dehydration plants in the Habiganj gas field. The processed gas is supplied to Titas Gas Transmission & Distribution Co. Ltd. (TGTDCL), Jalalabad Transmission & Distribution Co. Ltd. (JDTDCL), and the Gas Transmission Co. Ltd. (GTCL). There are nine vertical wells and two directional wells. The wells are located approximately 14 km apart. There are two shut-in wells with water invasion and sand problems.

4.2.2.4 Narsingdi Gas Field, Block 9, BGFCL

The Narsingdi gas field is located in the Narsingdi area in Shibpur upazila which is approximately 45 km from Dhaka. The field is at the north peak of the large Bakhrabad anticline. The Narsingdi gas field structure was named the A 2 peak by Shell in the 1960s. At that time, Shell decided that it was a prospect with high risk. During 1984 and 1986, Petrobangla completed a seismic survey in the field area and reevaluated the prospect. Petrobangla then decided that the field had the potential of 2,474 BCF. During exploration two gas-bearing sandstone reservoirs were confirmed and the lower reservoirs were also tested. Production began in 1996 and as of June 2010 the cumulative production was 111 BCF. Recoverable reserves are estimated to be 345 BCF and remaining reserves are 239 BCF. Current production rates from two producing wells are 34 MMCF per day. The produced gas is processed and supplied to Titas Gas Transmission and Distribution Co, Ltd (TGTDCL).

4.2.2.5 Meghna Gas Field, Block 9, BGFCL

The Meghna gas field is located in the Brahmanbaria area. In 1953, a gravity anomaly was identified and confirmed by a survey completed by Shell. During the 1984 to 1986 timeframe, Petrobangla completed another seismic survey. In 1990, a test well was completed and a structure was identified with six gas-bearing sandstone reservoirs at depths between 2,850 meters and 3,020 meters. The field produced 36 BCF of gas while on production during 1997 to 2007. Recoverable reserves are estimated to be 101 BCF and remaining reserves are 65 BCF. Production in the Meghna field was suspended, but resumed in September 2010. The field was recently producing 10 MMCF per day.

4.2.2.6 Sylhet (Haripur) Gas Field, Block 13, SGFL

The Sylhet gas field is located in Sylhet city in the Sylhet area which is 225 km northeast of Dhaka. The Dupi Tila period rocks are exposed on the surface. The first well was drilled in 1955 based on geological exploration data. At that time, three gas reservoirs were confirmed at a depth of 2,377 meters. During completion, a blow out occurred in the abnormally overpressured formation due to a poor cement job. During the fire, the drilling rig and the auxiliary equipment disappeared underground. The blow out created a fissure in the ground that extends to a nearby hill where there is evidence that the fire is still burning.

In 1956, a second well was drilled and another blow out in the same abnormal over pressured zone occurred at a depth of 2,818 meters.

In 1957, a third well was drilled to a depth of 1,800 meters. This well was completed in the upper portion of the gas-bearing sandstone reservoir and the lower portion was completed in two reservoir intervals. In 1969, formation water increased in the lower reservoir and production from that zone was shut-in. The well continued to produce from the upper reservoirs until 1988, at which time, the upper reservoirs of the well were shut-in as a result of increased formation water invasion.

In 1962, a fourth well was drilled, however, an abnormal overpressured zone was encountered at a depth of 338 meters and the well was abandoned for safety reasons.

A fifth well was drilled next to the fourth well to monitor pressure behavior at the shallow horizon. The fifth well was abandoned for technical reasons.

In 1964, the sixth well was drilled to a depth of 1,515 meters. The upper and lower layers of the Bokabil sandstone beds were completed in two zones. In 1993, production from the lower reservoir was shut-in because of water invasion. The upper reservoir is currently producing at a rate of 2 MMCF per day. This well is expected to be shut-in in the near future. Cumulative production in the field as of June 2010 was 189 BCF.

A seventh well was drilled by BAPEX to a depth of 2,009-2,033 meters. This well is the first oil discovery in Bangladesh and initial production rates were 350 barrels per day. This well was shut-in in July 1994 because of formation water invasion. The cumulative oil production was 560,869 barrels. In March 2005, this well was re-entered and completed as a gas well. Initial gas rates were 15 MMCF per day. The well is currently shut-in and a workover is planned in the future. Gas from this field is processed in a silica gel type gas processing plant located in Haipur with a processing capacity of 30 MMCF per day.

4.2.2.7 Kailash Tila Gas Field, Block 13, SGFL

The Kailash Tila gas field is located at Gulapganj in the Sylhet area which is approximately 300 km northeast of Dhaka. The Kailash Tila structure is based on analog seismic data from a seismic survey completed by Shell in 1960. The Shell data indicates that the anticline structure is a 4-way closure. In 1961, the first well was drilled to a depth of 4,138 meters. The second well and third well were drilled in 1988 and began producing in 1992. Afterward, the fourth well was drilled and the production rate was 65 MMCF per day. From 2006 to 2007, the fifth well and sixth wells were drilled. By the end of June 2010, the field cumulative production was 495 BCF. Recoverable reserves are estimated to be 2,880 BCF and remaining reserves are 2,400 BCF. The fifth well was recently shut-in as a result of increased water production. There is a silica gel type gas processing plant that has been in operation since 1983 with a capacity of 30 MMCF per day. There is also a molecular sieve turbo expander gas processing plant that has been in operation since 1995 with a capacity of 90 MMCF per day. To increase gas production in this field, the drilling of two more wells is planned in the near future.

4.2.2.8 Rashidpur Gas Field, Block 12, SGFL

The Rashidpur gas field is located approximately 100 km northeast of Dhaka. The structure of the field is an anticline extending north and south as identified by a seismic survey conducted by Shell during 1959 and 1960. The first well was drilled in 1960 confirming two gas-bearing sandstone reservoirs. In 1961, the second well was drilled to a depth of 4,593 meters. Research indicated that the lower sandstone reservoir was water. Subsequently, five more wells were drilled and began producing in 1993. By the end of June 2010, cumulative field production was 466 BCF. Recoverable reserves are estimated to be 3,134 BCF and remaining reserves are 2,677 BCF. The second and fifth wells are currently shut-in as a result of increased water production. The five wells are currently producing at a rate of 50 MMCF per day.

Remedial work on the second and fifth wells is planned. The drilling of an eighth well is also planned. There are four gas processing plants operating in the field, namely: a glycol type processing plant with a 60 MMCF per day capacity, a silica gel type processing plant with a 70 MMCF per day capacity, and two silica gel type processing plants with a 45 MMCF per day capacity.

4.2.2.9 Beani Bazar Gas Field, Block 14, SGFL

The Beani Bazar gas field is located 15 km east of the Kailashtilla gas field. The structure of the gas field was identified by the PSCO in the early 1960s; however, geological research was completed by the Oil and Gas Development Corporation (OGDC) at a later time. In 1971, Prakla Seosmos completed a 12-fold seismic survey. After the seismic data was analyzed, the first well was drilled between 1980 and 1981 confirming the two gas-bearing sandstone reservoirs. The structure is 12 km (north and south) and 7 km (east and west) with a 425 meter closure. The second well was drilled between 1988 and 1989 and began producing in 1999. As of June 2010, cumulative production was 62 BCF. Recoverable reserves are estimated to be 137 BCF and remaining reserves are 77 BCF. The two producing wells are currently producing at a rate of 15 MMCF per day. The silica gel type gas processing plant from the Feni gas field was transferred to location 1 in the Beani Bazar gas field. The gas processing plant test operation was completed in May 1999 and production officially began in July 1999.

4.2.2.10 Saldanadi Gas Field, BAPEX

The Saldanadi gas field is located in Brahmanbaria near the Indian border which is 75 km east of Dhaka. The Saldah anticline is a part of the large Rukhia structure which extends north and south. The structure was identified by BAPEX using old seismic data. The first well was drilled in 1996 confirming the two gas-bearing sandstone reservoirs and classifying the field as discovered. The first well began producing in1998. The second well was drilled in 1999. An unconformity was identified in the second well and the reservoir sandstone was not continuous. Cumulative production from both wells is 62 BCF. Recoverable reserves are estimated to be 275 BCF and remaining reserves are 213 BCF. Currently, the field is producing at a rate of 10 MMCF per day.

4.2.2.11 Fenchuganj Gas Field, Block 14

The Fenchuganj gas field is located approximately 200 km northeast of Dhaka. The surface structure of the Fenchuganj anticline is visible from air and satellite photos. The contour was identified by the results of an analog seismic survey completed in 1957 by PPL. A test well was drilled in 1960 and a gas show was observed.

A seismic survey was conducted by Prakla Seismos at the request of Petrobangla and under the technical support of Germany to review the anticline structure map. The results of the seismic survey indicated that the first well was drilled southwest of the center structure. Petrobangla drilled a second well during 1985 and 1986 to a depth of 4,977 meters. The well log results identified five sandstone reservoirs that contain hydrocarbons. The open hole test was completed five times resulting in gas production. Oil was also found in one of the lower sandstone reservoirs. A third well was drilled and began producing in 2004. As of June 2010, the cumulative field production was 72 BCF. Recoverable reserves are estimated to be 329 BCF and remaining reserves are 260 BCF. The current production rate is 27 MMCF per day.

4.2.2.12 Shahbazpur Gas Field, Block 10, BAPEX

The Shahbazpur gas field is located in the Bhola area which is approximately 140 km south of Dhaka. Petrobangla completed a seismic survey in this area during 1986 and 1987 and selected a drill site. BAPEX drilled the first well during 1993 and 1994 to a total depth of 3,631 meters. Gas was discovered in several sandstone horizons. A second well was drilled and the field was put on production in 2010. Daily production rates in the field are 7 MMCF per day. Cumulative field production is 2 BCF. Recoverable reserves are expected to be 261 BCF and remaining reserves are 259 BCF. It is estimated that 70 MMCF per day could be produced in the field in the near future.

4.2.3 Petrobangla Owned Undeveloped Gas Fields

4.2.3.1 Begumganj Gas Field

The Begumganj gas field is located in the southern region of Bangladesh. Recoverable (Proven+ Probable) reserves are estimated to be 33 BCF.

4.2.3.2 Semutang Gas Field

The Semutang gas field was discovered by OGDC in 1970. The structure is visible on the surface by outcrops of the Dupi Tila and Tipan sandstones. The estimated recoverable reserves are 318 BCF.

4.2.3.3 Kutubdia Gas Field

In the mid 1970s, Union Oil (later called Unocal) discovered the Kutubdia gas field which is located south of the coastal island of Shahbazpur, Hatia during offshore exploration. Recoverable reserves are estimated to be 46 BCF.

4.2.4 IOC Operated Gas Fields

4.2.4.1 Jalalabad Gas Fields, Block 13, IOC: Chevron

The Jalalabad gas field is located approximately 200 km northeast of Dhaka. The Jalalabad structure was identified by Petrobangla under the technical support of Germany. At that time, the structure was selected as a drilling site under the support of Germany. Those projects were never realized. In 1987, the PSC of this area was given to Scimitar Oil and the first well was drilled in 1989. Gas was discovered in three sandstone reservoirs. The anticline structure is SW-NE in direction. The PSC of block 13 in Scimitar that fell through in 1995 and was given to Occidental. By 1998, Occidental drilled four additional wells, three of which were gas wells. Production from those wells began in February 1999. In 1999, Unocal became the operator of this field. Unocal laid 15 km of pipeline to the gas processing plant and to the existing north and south transmission lines. The cumulative field production is 573 BCF. Recoverable reserves are estimated to be 1,128 BCF and remaining reserves are 555 BCF. Currently field production is 155 MMCF per day. If current production rates continue, depletion is expected to occur within 3 to 4 years. Based on a 3D seismic survey, Chevron is optimistic regarding future production in the Jalalabad field.

4.2.4.2 Moulavi Bazar Gas Field, Block 14, IOC: Chevron

The Moulavi Bazar gas field is located in the Kalapur, Srimangal, Moulavi Bazar area which is approximately 170 km northwest of Dhaka. Under the supervision of Germany, a digital multi-fold seismic survey was completed and a new structural drawing based on the seismic results was completed. After reviewing the results, the structure was selected as an exploration target which was funded by the German government. This project was never realized. An additional seismic survey was completed by BAPEX during 1990 and 1991. In 1995, the mine sites of blocks 12, 13 and 14 were awarded to Occidental. In 1997, Occidental started drilling the first well. The well was not completed because there was a blow out at 840 meters. In 1999, Unocal took over the project and drilled a second well to a depth of 3,510 meters. The second well confirmed the presence of the multi-layered, gas-bearing sandstone formation. A third well was drilled to research the scale of the gas field. In 2003, Chevron acquired Unocal and concluded a Gas Purchase and Sales Agreement (GPSA) with Petrobangla. Chevron drilled three production wells that began producing in 2005. Chevron also constructed a gas processing plant with the processing capacity of 150 MMCF per day and laid 24 km of pipeline. Cumulative gas production is 162 Bcf. Recoverable reserves are estimated to be 494 BCF and remaining reserves are 332 BCF. Daily field production rates are 56 MMCF per day.

4.2.4.3 Bibiyana Gas Field, Block 12, IOC: Chevron

The Bibiyana gas field is located in the Habiganj area which is approximately 220 km northeast of Dhaka. The field is a long anticline structure in the north and south direction with a 14 km (L) and 4 km (W) closure. During 1997 and 1998, Occidental USA identified the Bibiyana gas structure and drilled the first well in 1999. The first well was drilled to a depth of 4,014 meters. Something fell in the wellbore and got stuck at a depth of 3,618 meters blocking test access to the lower zones. There were six tests performed on the upper zones of the formation. A second well was drilled to a depth of 4,276 meters and tests in the lower zones of the formation were completed. The test results from the first two wells indicated that the formation consists of nine gas-bearing sandstone reservoirs. During 1998 and 1999, a 3D seismic survey was completed. In 1999, Unocal obtained the rights for blocks 12, 13, and 14 and became the operator of the Bibiyana gas field.

After Chevron acquired Unocal, five wells were drilled in the southern area and seven wells were drilled in the northern area. Chevron also installed a gas processing plant with a capacity of 600 MMCF per day and laid 42 km of pipeline from the gas processing plant to Muchai. Production began in March 2007. The cumulative field production as of June 2010 was 735 BCF. Recoverable reserves are estimated to be 4,532 BCF and remaining reserves are 3,797 BCF. Gas production rates as of June 2010 are 692 MMCF per day, making it the largest gas field in Bangladesh.

4.2.4.4 Sangu Gas Field, Block 16, IOC: Cairn/Santos

Cairn Energy Plc., a UK based company, has been involved in oil and gas exploration and development projects in Bangladesh since 1974. A 2D seismic survey was completed in block 16 which was obtained by PSC. A gas field was discovered in 1996. The gas field is offshore approximately 45 km southwest of Chittagong, Bangladesh. An offshore drilling platform was constructed in a water depth of approximately 10 meters. At that time, nine production wells were drilled. Production began in 1998 after construction of a 520 MMCF per day capacity gas processing facility in the Chillimpur terminal in Chittagong. The drilling platform and the gas processing facility are linked by a 20” pipeline. The initial wellbore pressure was 4,600 psi and the current wellbore pressure is around 1,000 psi. As of June 2010 there are six producing wells that produce at a rate of approximately 31 MMCF per day. The cumulative production is 476 BCF. Recoverable reserves are estimated to be 771 and remaining reserves are 295 BCF. The structure of the gas field is a NW-SE trending anticline structure. Cairn sold its interest to Santos in 2010.

The reservoir is a sandstone with ten gas-bearing zones. The primary target is the SG 3155 formation which is 50% of the entire structure. It is predicted that production from this field will cease within the next few years.

4.2.4.5 Bangora Gas Field, Block 9, IOC: Niko/Tullow

The Bangora gas field is located 100 km southeast of Dhaka. Tullow Oil Plc has been involved in oil and gas exploration activities in Bangladesh since 1997. In 2001, Tullow obtained a PSC for the mine site of block 9. Tullow is the field operator but field development is the collaborative effort of three companies. The breakdown of the collaboration is: Tullow (30%), Niko (60%) and BAPEX (10%). Tullow identified the Lalmi-Bangora large anticline structure and drilled the third well in the Lalmi area in May 2004. At that time, a gas reservoir was discovered as a result of well testing. The first well drilled in Bongora was located 40 km north of the third well drilled in Lalmi. That well was drilled to a depth of 3,636 meters and a gas-bearing sandstone reservoir was discovered between 2,580 meters and 3,285 meters. The test results indicated that the production rate capability is 25 MMCF per day. In May 2009, the fifth well was drilled and put on production. The gas is processed in a gas processing plant with a capacity of 120 MMCF per day. Currently, the production data and a 3D seismic survey are interrelated with the Lalmi structure. As of June 2010, the cumulative production was 116 BCF. Recoverable reserves are estimated to be 621 BCF and remaining reserves are 505 BCF. The daily production rates are 107 MMCF per day.

4.2.4.6 Feni Gas Field, block 15, IOC: Niko

The Feni gas field is located approximately 125 km from Dhaka. During 1975 and 1976, a seismic survey was completed by the Taila Sandhani Company. At that time, they named the structure Feni. During 1979 and 1980, another seismic survey was completed, resulting in a new structural drawing with a long and thin anticline structure. The first well was drilled in June

1960. An overpressured zone was found at a depth of 3,200 meters and the upper reservoir was evaluated. The two producing intervals of the gas-bearing sandstone reservoir were identified by the well logs and test data. The Feni gas field began producing in 1991. The second well was drilled in 1994 and the production began in 1995. The production was shut-in in 1998 as a result of increased formation water production.

In 2003, Niko Resources Ltd. signed the joint venture with BAPEX to promote the development and production of the Feni and Chattak gas fields. The Feni gas field ceased production in 1996 and the Chhatak gas field ceased production in 1982. In late 2004, Niko Resources Ltd. restarted production at a rate of 20 MMCF per day. In January 2005, the production processing plant was reinforced. At that point, all activity ceased. As of June 2010 daily production rate was 1 MMCF per day. Cumulative production is 63 BCF. Recoverable reserves are estimated to be 130 BCF and remaining reserves are 67 BCF.

4.2.4.7 Kamta Gas Field, Block 9, Suspended: Petrobangla

The Kamta gas field is located near Kaliganj in the Gazipur area which is approximately 17 km north of Dhaka. The Kamta gas field was discovered by Petrobangla in 1982. Production began in November 1984 with a daily rate of 20 MMCF per day. By 1988, the production rate had decreased to a rate of 3 MMCF per day as a result of increased water production. The field was eventually shut-in in 1991. The cumulative production is 21 Bcf. Recoverable reserves are estimated to be 50 BCF and remaining reserves are 29 BCF.

4.2.4.8 Chattak Gas Field, Block 12, Suspended: Niko & Bapex

The Chattak gas field is located approximately 2.5 km northwest of Sylhet city. The structure of the gas field is the north end of the Surma basin which is an ESE-WNW anticline structure. In 1959, PPL completed a 75 km seismic survey. In 1959, the first well was drilled to a depth of 2,135 meters. Nine gas-bearing sandstone reservoirs were identified between 1,090 meters and 1,975 meters. The field began producing in 1960. The field was shut-in in 1986 as a result of increased water production. Cumulative production is reported to be 26 BCF. Recoverable reserves are estimated to be 474 BCF and the remaining reserves are 448 BCF. It appears that a considerable amount of gas has not been recovered and there is potential for gas recovery in the future.

In 2000, Niko Resources of Canada (Niko) completed a collective reserves research program with BAPEX. There are outstanding legal issues between Petrobangla and Niko regarding the Joint Venture Agreement (JVA). The situation is expected to be settled soon and it is expected that a development program in the Chattak gas field will be initiated in the future. A 3D seismic survey has already been completed with positive results.

4.3 PLANNED EXPLORATION

The Government has outlined a plan to explore, discover, and improve new gas fields. The salient features of the short, medium, and long term objectives for the planned and ongoing programs are as follows:

4.3.1 FY 2010 Plan

The short term plan to increase gas production is outlined below. The expected result of the short term exploration and development plans was to increase production by 95-100 MMCF per day, to be supplied to the national grid by June 2011.

Actions to be taken

- *Salda gas field* - There are plans to workover one well. The results of the workover are expected to increase production by 15-20 million cubic feet per day.
- *Fenchuganj gas field* – There are plans to drill two evaluation/development wells. The two new development wells are expected to increase production by 35 million cubic feet per day.
- *Sundalpur gas field* – There are plans to drill one exploration well in the Sundalpur gas field in the Noakhali District. The exploration well is expected to increase production by 15 million cubic feet per day.

- *Sangu gas field* - An exploration/development well in the southern area of the Sangu gas field is expected to increase production by 30 million cubic feet per day.

4.3.2 Short Term Plan (expected completion by June 2013)

The short term plan includes the drilling of 39 exploration and development wells. The 39 planned wells are expected to add more than 1.9 billion cubic feet of gas production capacity per day by 2013.

Gas shortages have resulted in the temporary closure of some power plants and fertilizer factories that have severely interrupted the generation of electricity and fertilizer. Importing LNG is a viable option for supplementing the natural gas supply. The medium term plan includes importing up to 500 million cubic feet per day of LNG to convert to gas. An agreement with Qatar has already been signed to import LNG, in which Moheshkhali has been selected as the location for installation of the floating LNG receiving and storage station. Land acquisition is under way to construct a pipeline from Moheshkhali to Anwara and a LNG terminal. The process is expected to be complete by 2013.

4.3.2.1 Actions to be Taken by the National Gas Company

- *Salda, Titas, Fenchugonj, Semutang, Shabazpur, and Bakhrabad gas fields* – The drilling of ten development wells are planned. These wells are expected to produce 190 MMCF per day.
- *Kapasia, Srikail, Sundalpur, and Mobarakpur gas fields* - Exploration well sites have been identified using seismic data. The planned wells are expected to produce 95 MMCF per day.
- *The Fast Track Program* – This program was developed to address the increasing gas demand and supply shortage issues. The program includes plans to drill four development wells in the Titas gas field and one development well in the Rashidpur gas field. There is also one planned workover in the Rashidpur gas field. This program also includes plans to indentify and drill new development wells using data collection,

processing, and analyses of a 3,100 kilometer 2-D seismic survey. If the exploration program is successful, gas reserves and gas production will increase in the future.

- *Muchai, Ashuganj, and Elenga* – To ensure optimum gas supply and maintain steady pressure, compressor stations are planned to be installed at Muchai, Ashuganj, and Elenga. The compressor at Muchai will be installed by November 2011, while the compressors at Ashuganj and Elenga will be installed by December 2012.
- *Discovery of a New Gas Structure* – In recent months, BAPEX interpreted 283 kilometers of 2D thirty-fold seismic data, in which a potential gas structure (Sunetra) was identified. Sunetra spreads across the Sunamganj and Netrokona districts. Based on the results of the interpretation, the structure is expected to have a remarkable gas reserve. Land acquisition, development of infrastructure, and other relevant activities are being done by BAPEX in order to begin drilling an exploration well at the end of October 2011.

4.3.2.2 Actions to be Taken by International Oil Companies

Chevron plans to drill 9 development wells at Moulvibazar, 6 development wells at Bibiyana, and 3 development wells at Jalalabad. These wells are expected to produce 1,000 MMCF per day.

4.3.3 Intermediate Term Plan (expected completion by December 2015)

The intermediate term plan includes local and international oil companies drilling exploratory wells. Exploratory wells drilled by local oil companies are expected to produce 180 MMCF per day. Exploratory wells drilled by international oil companies are expected to produce 700 MMCF per day. In total, 880 MMCF per day is expected to be added to the national grid by December 2015.

4.3.3.1 Actions to be Taken by the National Gas Company

The National Gas Company plans on drilling 9 development wells, 5 of which are planned in Sylhet, Kailastilla, and Rashidpur gas fields. There are 4 development wells planned in the Titas gas field. Expected production from these 9 wells is 180 million cubic feet per day.

4.3.3.2 Actions Taken by International Oil Companies

An offshore bidding round that took place in 2008 resulted in an agreement with ConocoPhillips and Tullow for 3 offshore blocks. Subject to the signing of a production sharing contract (PSC), a target has been set to produce 200 MMCF daily as a result of exploratory activities. A plan for eleven development wells in Bibiyana, Jalalabad, and Moulvibazar gas fields in Blocks 12, 13, and 14 is set to supply 500 MMCF daily to the national grid.

4.3.4 Summary

The target daily production rate outlined in the short, medium, and long term plans would increase gas supply by 2,325 to 2,380 MMCF per day. Exploration and drilling programs are expected to increase the gas supply by 1,825-1,880 MMCF per day. Imported LNG is expected to increase the gas supply by 500 MMCF per day.

4.3.5 Steps to Ensure the Implementation of the Plans

Although the implementation of the current year, short term, and intermediate term plans would add to the natural gas supply, it will not completely satisfy the expected future gas demand. To ensure the execution of the plans to increase the natural gas supply, the following steps must be taken:

- Ensure provision of funds as per the plan.
- Arrange for a timely bidding round for onshore and offshore blocks.
- In an effort to strengthen BAPEX, the purchase of higher quality machinery, advanced technology, and build up of manpower is necessary.

- Ensure the drilling and development of wells as per the plan through an uninterrupted work procedure and effective monitoring of international oil companies.
- Quick accomplishment of the demarcation of the maritime boundary with India and Myanmar for award of offshore deep sea area blocks.

4.4 GAS PRODUCTION AUGMENTATION (PREPARED BY SCHLUMBERGER) [38]

Data from 59 wells in eight gas fields, namely Titas, Habiganj, Bakhrabad, Kailas Tila, Rashidpur, Sylhet, Fenchuganj and Shahbazpur, have been analyzed using nodal analysis. The analysis was primarily based on historical production data of gas, water, and condensate, pressure behavior, well logs, test data, and well configurations. Individual well system models were prepared and validated with past performance of these wells. Based on the model and analysis, work recommendations to increase production have been identified and are summarized in Table 4-2 and Table 4-3.

Table 4-2 Summary of Gas Production Increase (Estimated)

Recommendations	Estimated Gas Increase	Estimated Cost
Surface adjustment	120-200 MMscfd	0.16 Million USD
Wireline Intervention	70-120 MMscfd	6.15 Million USD
Rig Workover Intervention	200-250 MMscfd	105.00 Million USD
Total	**350-500 MMscfd**	**111.31 Million USD**

Table 4-3 Field-wide Gas Production Increase (Estimated)

[MMscfd]	**Habiganj**	**Titas**	**Bakhrabad**	**Kailash tila**	**Rashidpur**	**Shylet**	**Fenchuganj**	**Shahbazbur**
Surface adjustment-	40-75	30-70	0	35-40	3-6	4-7	1-2	1
Wireline Intervention	18-25	25-35	12-22	2-5	12-15	3-6	3-5	2-3
Rig Workover Intervention	24-30	50-75	25-35	40-50	25-30	10-18	4-5	2-4
Total	**60-110**	**100-160**	**25-30**	**70-80**	**35-45**	**16-30**	**6-10**	**4-7**
Current field Production	220	400	32	90	50	9	23	7
Facility Limit	420	660	240	90	220	30	60	40

[38] M/S Schlumberger SEACO Inc, 23 May 2011, SLB_Prod_Aug.doc, 110707_comments_on_Augmentation_hcu1.docx

Several steps were recommended to increase production as outlined above. A control device on the PCV can be installed on wells that can be adjusted to increase the flow from a well as long as the reservoir permits. This type of adjustment is actually done from time to time in the fields. However, at a later stage when the plant upstream pressure declines by such a level that the concerned PCV cannot handle the same volume with its designed operating range, the PCV might need to be re-sized based on the process requirement. Since 2010, BGFCL has increased production from the Titas field by 43 MMscfd by adjusting the PCV. The back pressure can also be reduced to increase flow. In some wells, high skin factors can be removed to increase productivity by reperforating and acidizing the area. This may not be applicable for all wells, however, as there are restrictions in completion strings and many of the reservoir rocks are argillaceous sandstones, which hardly react with acid. Another suggestion to increase production was to replace the tubing with larger diameter tubing. This could be considered on a case by case basis, but Titas, Habiganj, Kailas Tila, and Rashidpur gas fields were identified as good candidates for replacing the tubing.

Wireline and rig workover interventions would require temporary shutdowns of wells. This is not deemed to be possible at the current time due to the current gas shortage in Bangladesh.

4.5 CONVENTIONAL GAS RESOURCE EXPLORATION

4.5.1 Prospects

A prospect is an oil or gas exploration opportunity that has sufficient data to suggest a drilling location. The data has been mapped and the resulting predicted hydrocarbon accumulation is deemed to be economic if all necessary aspects are present. These prospects are considered to be conventional resources.

4.5.2 Leads

A lead is an oil or gas exploration opportunity with sufficient data to suggest a possible prospect. Either the data is insufficient to confirm the prospect or the work is incomplete on evaluation of the data that could raise the lead to prospect status.

4.5.3 Unmapped Resources

The category of Unmapped Resources, as used in this report, includes additional prospective resources from conventional accumulations that have not yet been identified as being in a specific prospect or lead. This evaluation has been built on the foundation of the resource estimate report prepared by the USGS in 2001. The USGS assessment divided the country into six Assessment Areas:

1. The Surma Basin assessment unit;
2. Easternmost Extremely Folded assessment unit;
3. High-Amplitude Faulted Anticlines assessment unit;
4. Moderately Folded Anticlines assessment unit;
5. Western Slope assessment unit;
6. Western Platform assessment unit.

These areas are shown on Figure 4-2. The approach used by the USGS was to assign to each assessment unit a triangular probability distribution for the number of fields to be discovered, and a lognormal distribution for the size of fields to be discovered. These same distributions were used for this report.

Because maps showing the exact location of each prospect and lead were not available to Gustavson, when blocks were split between assessment areas, the number of prospects and leads in those blocks were apportioned into the assessment areas roughly proportionally to the area of the block within each assessment area. For example, half of Block 3's prospects and leads were assigned to the Western Slope area and half to the Western Platform area. Some areas had a maximum number of discoveries in the distribution smaller than the number of mapped prospects and leads in that area: those areas were assigned no unmapped resources in this Study.

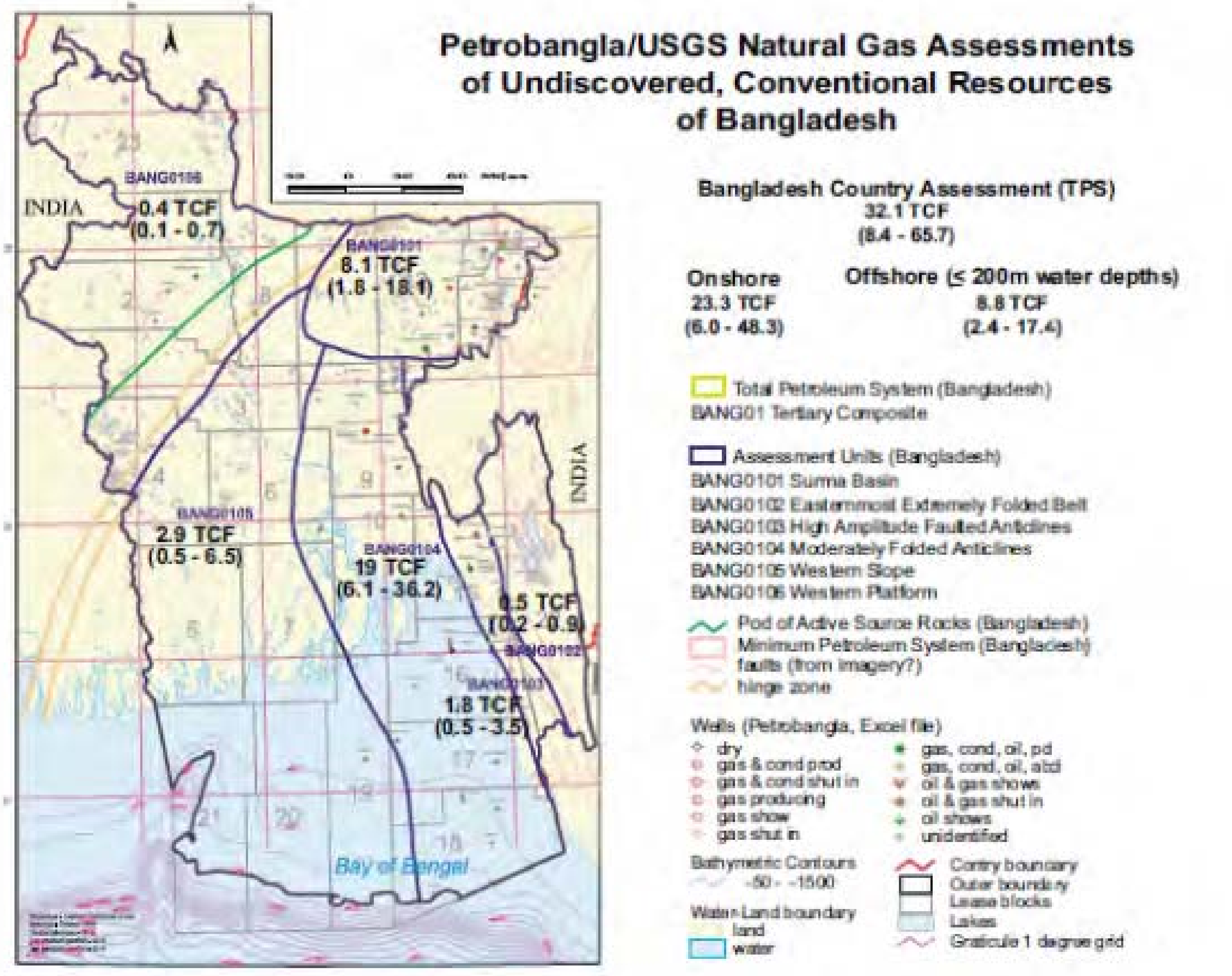


Figure 4-2 USGS map of resources in Bangladesh by region

4.6 UNCONVENTIONAL GAS RESOURCES

Bangladesh is now suffering an acute energy crisis. There is a large difference between energy demand and supply and the government is trying to solve the problem. It is very difficult to cope with the ever increasing demand with conventional energy extraction technologies. Reducing the dependency on natural gas is also necessary. Importing fuel is an alternative solution, but may be costly. It is prudent for Bangladesh to identify alternative domestic energy sources such as coalbed methane (CBM), shale gas, and thin beds.

4.6.1 Coal Bed Methane (CBM) [39]

Many coal producing countries are evaluating the option of extracting methane gas, gas trapped in coal seams that is also known as coalbed methane (CBM), before extracting coal by mining. CBM projects could provide additional gas resources to assist in meeting gas demand.

In the south Asian region, CBM is still in the experimental stage. China has implemented various policies that provide incentives to participants of CBM and CMM (coal mine methane) development projects. India has a production sharing contract framework and has invited bids from international companies interested in CBM exploration and development. CBM is a capital intensive and specialized sector. Bangladesh needs to develop a conducive environment and an incentive policy to attract international companies and investment. Initially, CBM potential must be evaluated with consideration of expected returns and benefits of investment. The results of that evaluation will help Bangladesh identify and suggest incentives, and suitable policy measures required to invite foreign participation.

In most of the coalfields in Bangladesh, the coal beds are very deep. Methane gas trapped in the coals can be extracted with very little disturbance to the current human habitat and agricultural fields. Coal bed methane (CBM) is a form of natural gas that is composed mostly of methane, with some carbon dioxide. It is often referred to as unconventional because it is stored within the matrix of the coal itself instead of within the pores of the host rock.

[39] This section is based on "Coal Bed Methane (CBM): A Compilation" by Hydrocarbon Unit (HCU), 2011

Coal miners have known about the presence of CBM in coal mines for centuries. In the past it was viewed as an explosive danger and was something to be avoided or controlled. Extraction of CBM is technologically feasible and economically viable. CBM extraction can provide immediate relief to the current energy shortage. The extraction of CBM does not exclude coal mining using open-pit or underground mining at a later time. In fact, the extraction of CBM before coal mining actually reduces the dangers of methane explosions during underground mining.

Coal-bed methane (CBM) is an economic source of pipeline-quality methane gas generated and stored in coal beds. It is a widely occurring, exploitable resource that can be easily recovered.

Coal acts as both source rock and reservoir rock for methane. Methane is generated by microbial (biogenic) or thermal (thermogenic) processes shortly after burial and throughout the digenetic cycle resulting from further burial.

Much of this gas is physically adsorbed on coal surfaces in areas with coal micro porosity. One short ton of coal can produce about 1,300 m^3 of methane. Hydraulic pressure, rather than a pressure seal or closed structure (common for conventional oil and gas fields), is the major trapping force for CBM.

Coal is extremely porous (openings), but has low permeability (connected openings). Gas adsorbed on coal is predominantly methane, but much of it cannot be economically produced without the presence of natural fractures (cleats) to connect the pores. Cleats allow the desorbed gas to flow to the well.

4.6.2 Shale Gas[40]

Natural gas produced from shale is considered to be an unconventional hydrocarbon and is known as "shale gas". Shale gas is primarily composed of methane (90% or more methane). In contrast to most conventional hydrocarbon plays, in the case of shale gas the strata are both the reservoir and the source rock. Since permeability and porosity are very low in this reservoir the application of the technology of artificial fracturing and horizontal drilling are necessary to exploit this resource.

Shale is deposited as mud and silt in depositional environments charterized by quiet water. The very fine-grained sediments and organic matter from algae, plants, and animal debris, form the shale. The included organic matter when buried and mature generates natural gas. Shale gas is stored within the shale bed and in macro-porosity systems (fracture porosity), micro-pores, or adsorbed onto minerals or organic matter. Gas trapped in un-fractured shale (low permeability on the order of 0.01 to 0.00001 millidarcies) cannot move easily within the rock.

Hydraulic fracturing involves pumping a fracture fluid into a formation at a calculated, predetermined rate and pressure to enhance natural fractures and generate new fractures in the target formation. The additional permeability created by fracing allows gas to flow more readily toward the well bore. Frac fluids are primarily water-based fluids mixed with additives which help the water carry sand “proppant” into the fractures. The sand “proppant” remains in the formation to "prop" open the fractures. Hydraulic fracturing and long reach horizontal drilling technology have made the development of shale gas viable.

4.6.2.1 International Experience

In the United States, shale gas exploration and production has increased rapidly and is the most active exploration play in the United States. The estimated cost of producing shale gas is between $6 and $11 per MMBtu (Million British Thermal Units). The Henry Hub spot price

[40] This subsection is based on material from several sources including “Workshop Details on Shale Gas” HCU ,2011; Shale Gas Introduction”, Sagar, R SPL, Dhaka, 2011; “Shale Gas ,Energy & Power”, Hossain M.M, 2011; “Shale Gas” HCU, 2011

averaged $4.05 per MMBtu in August 2011. There are some countries in Europe and Asia that are working on incorporating shale gas resources into their energy mix. Recently China and India incorporated plans to harness shale gas resources into their future energy plan.

The United States has a long history in production of shale gas and has recently focused exploration and production attention on this resource. Advances in horizontal drilling techniques and hydraulic fracturing have made shale reserves more accessible and the price for natural gas encouraged companies to explore for this resource. Strong gas prices were necessary to exploit this resource since the technology involved is both time and money intensive. Natural gas prices in the United States have dropped from their peak levels and have an effect on the profitability of this resource.

In 2010 shale gas production in the United States accounted for 25% of the total U. S. production of natural gas.[41] In 2009 the Barnett Shale play in Texas produced 6% of all natural gas produced in the United States, excluding Hawaii and Alaska,[42] from more than 15,000 wells. As of the end of 2010, the Barnett Shale play had cumulative production of more than 9 trillion cubic feet of gas.[43] The total recoverable gas resources in four new shale gas plays (the Haynesville, Fayetteville, Marcellus, and Woodford) may be over 550 TCF.[44] There are around 35,000 wells under production in five major established shale gas plays in the US. From 1996 to 2008, production of shale gas increased from 0.3 to 2.02 TCF per year.

China set a target for the country to identify 50-80 percent shale gas prospects and 20-30 percent exploration and development blocks by 2020. China also set a goal to locate one trillion cubic meters of recoverable shale gas reserves, build 15-30 billion cubic meters per year of production capacity and produce 8-12 percent of China's natural gas from shale gas wells by 2020. Geological and geochemical characteristics of the black mud-shale in the Nenjiang and Qingshankou formations in China suggest a favorable mud shale gas zone. China National Petroleum Corporation (CNPC) has a target to produce 500 million cubic meters (mcm) of shale

[41] www.eia.gov, Pressroom
[42] Shale Gas Primer, 2009; U.S. Department of Energy
[43] The Railroad Commission of Texas
[44] www.eia.gov, Analysis & Projections

gas per day by 2015. In November 2009, the United States agreed to share information about gas-shale technology with China, and to promote US investment in Chinese shale-gas development.

In India, shale deposits are found across the Gangetic Plain, Assam, Rajasthan, and many coastal areas. Basins of preliminary interest identified by Indian geologists are the Cambay Basin in Gujarat, the Assam-Arakan Basin in northeast India, and the Gondwana Basin in central India. The shales in Gondwana and Cambay basins are being explored for evaluating the shale gas potential.

India and the United States have agreed to cooperate on clean technology and shale gas, and they signed an agreement for cooperation with respect to shale gas technology. Indian scientists consider shale gas to be an important energy independent resource for India and have expressed concern about its lack of technological know-how in this sector.

4.6.2.2 Shale Gas Prospects in Bangladesh

Strata that may be explored for shale gas in Bangladesh are not yet well known or specifically identified. Considerable work is necessary to investigate the potential shale gas plays that have been suggested. Source rock analysis, burial history and maturity, details of the rock facies, fracture analysis, geographic extent, and other factors will need to be researched and data gathered. The potential shale gas plays in Bangladesh include organic-rich shales of Eocene, Oligocene, and Miocene age that have been considered to be the source rocks for conventional gas and oil discoveries and shows in wells in the different regions of Bangladesh. There are several areas that warrant investigation for shale gas potential. These would be areas of the Bogra Shelf, Surma Basin, Hatia Trough, and Fold Belt in locations and at depths that would be expected to include source rocks that are mature to hydrocarbons.

Some data have been collected for rocks of Mesozoic through Tertiary age in Bangladesh showing the total organic content TOC and the hydrogen index (HI) indicating suitability and maturity of these potential source rocks. The TOC values range from 0.2 weight percent TOC to

16 weight percent TOC and greater[45]. A TOC value of 0.5 weight percent is considered the minimum organic content for a good source rock. Both oil-prone and gas-prone rocks have been sampled. Maturity is not well known for all of the potential strata. Additional work must be done. The fact that gas is produced in Bangladesh and oil is known from wells indicates that mature source rocks are present and could be exploited as shale gas plays.

Gustavson Associates has estimated the resource potential of a geographic area of 8,421 square kilometers along the Bogra Shelf where shales of Late Cretaceous through Early Eocene age may be buried at depths sufficient to place the strata within the hydrocarbon generation window. The expected depth of maturity along the Bogra Shelf is 3,000 to 5,500 meters. Shales of this same age would be expected to be mature at approximately 6,000 to 8,000 meters depth if present in the Surma Basin. Resources were assigned to an area of 7,706 square kilometers for the resource report. The same age shales, if present and of sufficient quality, would be expected to occur in the Hatia Trough and be mature at depth of 5,400 to 10,000 meters. Resources have been assigned to an area of 33,553 square kilometers of the region of the Hatia Trough. Pre- Miocene age shales are predicted to be mature at depths of approximately 3,000 to 6,500 meters in the region of the Fold Belt. Gas resources were estimated in this region for an area of 23,000 square kilometers.[46]

4.6.2.3 Shale Gas Development Initiative in Bangladesh

1. A committee has been formed by the Ministry of Energy & Mineral Resources under the leadership of the Director General, Hydrocarbon Unit to assess the potential for shale gas in Bangladesh and to make proper recommendations for its development.
2. The Hydrocarbon Unit has recruited an international consultant to study shale gas potential in Bangladesh.
3. Like the Indian Government, a delegation headed by the Director General of the Hydrocarbon Unit and other competent officials from the Energy Ministry and

[45] 2011 Resource Report, Gustavson Associates
[46] 2011 Resource Report, Gustavson

Petrobangla may visit the US Geological Survey, USA to discuss assistance in identifying and exploiting shale gas resources in Bangladesh.

4. An experienced shale gas consultant should be engaged for assessing the shale gas potential in Bangladesh and determine reserves and/or resources, if any.
5. A workshop/training is recommended for capacity building with the participation of officials and experts from concerned organizations.
6. As the USA is pioneer in shale gas development with experience in shale gas technology, Bangladesh can request support from the United States Geological Survey (USGS) to evaluate shale gas potential in Bangladesh as well as to improve technical know-how.

4.6.3 Thin Beds

Thin beds are simply thin pay zones that are too thin to show up on older logs. These pay zones are present in producing fields in Bangladesh but were not recognized when the wells were originally drilled because of the resolution of the logging tools. The inclusion of these zones might increase the net pay thickness and thus the reserves in existing fields considerably. One notable study has been done to identify these zones in the Bibiyana gas field. The results indicate that reserves for this field can be increased by more than 60 percent.[47] Some of the reservoir intervals within the lower Bokabil and underlying Bhuban Formations consist of thin-bed, interlaminated pay consisting of thin alternations of reservoir-quality sands and non-reservoir shales. These intervals were identified by thin-bed logging tools, in particular the STAR tool, a micro-resistivity device. These pays at Bibiyana, with thickness between 5 cm and 30 cm, represent over 60 percent of the net pay in the first two wells, as documented in Unocal's Evaluation Report of July 2000.

4.7 SUPPLEMENTAL ENERGY SOURCES

In order to meet energy demand, Bangladesh should consider new hydrocarbon exploration as well as other sources of energy including gas imports and other types of energy besides natural gas. Natural gas supply substitutes are identified and discussed below.

[47] 2011 Resource Report, Gustavson

4.7.1 LNG Imports[48]

LNG (Liquefied Natural Gas) brings to mind a big volume business using giant cryogenic vessels moving across seas and oceans. LNG is exported from Algeria to EU countries and from the Middle East, Malaysia, Indonesia to Japan and other Far East countries. Japan accounts for around 80% of the total volume of LNG traded in the Asia Pacific region.

LNG has now become a proven commercial technology for transporting natural gas. Major exporters of LNG include Algeria, Libya, Trinidad & Tobago, Oman, Qatar, UAE, Nigeria, Australia, Brunei, Indonesia, and Malaysia. Importers include the USA, Puerto Rico, Belgium, France, Greece, Italy, Portugal, Spain, Turkey, Japan, South Korea, and Taiwan. Japan is the world's biggest importer of LNG followed by South Korea and France.

LNG now accounts for 7 percent of the world's natural gas demand. The global growth rate of LNG business is 6 to 7 percent per year.[49] Natural gas is expected to become an increasingly important energy source world-wide for power generation, the production of petrochemicals, and transportation. A gas dominant energy environment would increase LNG trading. The decreasing cost of LNG liquefaction could also help the market grow. Continuous growth in spot and short term LNG trading would also help promote market integrations and advance the commercialization of LNG.

The major advantages of LNG are:

- Its density is 600 times that of natural gas in the gas phase.
- It can be stored above or below ground in specially designed double walled storage tanks.
- LNG can be transported to main ports, remote areas, and over long distance via LNG carriers or vessels, keeping LNG in chilled condition during transportation.

The major disadvantages of LNG include its capital intensive nature and stringent safety issues.

[48] This subsection is based on several sources including "LNG New Opportunity", Ahmed, N., Probe News Magazine , 2007; "Low Cost LNG" Ahmed, N., Probe News Magazine, 2007; "LNG Viable Alternative Energy & Power", Saleque, K.A. , 2009.
[49] Saleque, KA: '***LNG Viable Alternative Energy & Power***', 2009

The Bangladesh energy outlook has changed as a result of substantial gas shortage. Bangladesh is keen to import LNG to alleviate the gas shortage issues particularly the electricity needs. A Memorandum of Understanding was signed with Qatar to import the LNG equivalent of 500 MMCF per day.

In January of 2011, the Bangladesh government decided to initiate a plan for a floating LNG project. They have solicited the services of Eccelerate Energy to determine the LNG site location and estimate costs for the planned project.

The government intends to quickly implement the project to prevent a natural gas shortage related crisis from occurring in Chittagong before 2012. The main tasks of the project include the construction of a floating LNG receiving gas storage terminal in Moheskhali, the construction of a re-gasification infrastructure, and the construction of a Moheskhali-Chittagong Pipeline.

GTLC would have to install the pipeline from Mohashkhali to Chittagong. The entire LNG project will be implemented on a build-operate-transfer basis with an estimated cost of US $1.6 billion. Once the work order is issued, completion of the project is expected to take 18-24 months.

4.7.2 Natural Gas Pipeline Imports

There is a growing and urgent demand for natural gas in Bangladesh some of which could be supplied by natural gas imports via new pipelines. In the past, there was a plan to supply natural gas from Bibiyana gas field to the gas market in northern India. That plan was suspended because the Bangladesh government asserted that they would not export gas unless a strategic volume of reserves, enough reserves to support domestic demand for at least 50 years, were secured. The conditions changed and the people of Bangladesh argued that natural gas supply would not meet demand. Possible pipeline routes are from India or Myanmar.

In 2002, Reliance discovered a large gas field, Dhirubhai, east of the Bay of Bengal, India. The Dhirubhai gas field is located at KG-DWN-98/3 (D6) mining area and located in the KG sedimentation basin. This discovery stimulated investment and led to the discovery of other large gas fields. The gas field began producing in April 2009, 7 years after the field was discovered. It is expected that the discovery of the Dhirubhai gas field will continue to stimulate the Indian economy and secure the Indian energy supply. Bangladesh has had several meetings with India regarding importing natural gas to Bangladesh. The results of these meetings are unknown.

In 2004, Daewoo, a company based out of South Korea, discovered the Shwe gas field at the A-1/3 mining area off the western coast of Myanmar. Daewoo reports that gas reserves for 3 gas fields in the vicinity of the Shwe gas field are estimated to be 4.8 to 8.6 TCF. In February 2002, Bangladesh was in negotiations with Myanmar to import natural gas to Bangladesh via pipelines. During this time, Myanmar announced their intention to prioritize their natural gas exports to China and India. Myanmar disclosed that they would examine exporting natural gas to Bangladesh provided there was sufficient supply after exporting to China and India. Importing natural gas seems to be a very complex and sensitive issue with several speculations of the related countries. Last year, Russia and India expressed new interest in the Tri-Nation gas pipeline project initiating a new discussion.[50] However, there are also recent reports that this project may be abandoned.[51]

4.7.3 Coal[52]

Coal is one of the oldest sources of energy, although it has been viewed as a "dirty fuel" because carbon dioxide emissions per unit of energy production from coal are higher than for other fuels, such as natural gas. As a result of increased petroleum oil and natural gas prices, coal is being viewed as a major energy substitute for other energy supplies. Coal prices have increased

[50] Kaladan Press Network, May 7, 2011, http://www.kaladanpress.org/v3/index.php?option=com_content&view=article&id=3168:talks-with-burma-to-import-gas-tri-nation-gas-pipeline-talks-may-be-revived&catid=136:may-2011&Itemid=2

[51] http://www.thefinancialexpress-bd.com/more.php?date=2012-04-21&news_id=127358

[52] This subsection is based on material from 'The Study for Master Plan on Coal Power Development in the People's Republic of Bangladesh', JICA & Tokyo Elec Power Ltd ,2010; "Coal: New Energy Option for Bangladesh" Ahmed. N, Probe News Magazine , 2007; and "Coal Can Change the Destiny of Bangladesh" , Ahmed, N, Probe News Magazine, 2007

globally generating new interest in commercial exploration and exploitation projects by international coal companies.

There are five coal fields in NW Bangladesh with coal resources that have the potential to meet the immediate energy needs. There is some debate about the best methods for extracting the coal without endangering the socio-political and natural environment. There are many advantages and disadvantages of both open-pit and underground coal mining in a densely populated and agriculturally rich area like the Dinajpur and Rangpur districts.

Geological and hydro geological circumstances of the Gondwana coal basins of NW Bangladesh imply that neither multi-slice long wall mining method (MLMM), nor open pit mining method could be successful for its optimum production rates considering its surrounding environments. For example, the present underground mining operation in the Barapukuria coal mine reveals that only 10% (34 Mt) of the total in situ reserve coals (377 Mt) is recoverable by using MLMM. On the other hand, the open pit mining method, where recoverable rate is over 90%, would create devastating environmental degradation for valuable agricultural lands, damage of the water-bearing Dupi Tila aquifer, surface water contamination by mine wastages, acid mine drainage (AMD), replacement of densely populated villages, and other problems with ecosystems. The mining method thus, shall be selected with careful consideration of the above facts.

In the early 1960s, a coal deposit was discovered at Kuchma, Bogra district. The coal deposit was discovered while drilling for oil and gas at a depth of 1,000 meters from the surface. After the discovery, concerted efforts were made to find coal at economic depths. Substantial coal deposits have been discovered in the greater Bogra, Dinajpur, and Rangur districts in northwestern Bangladesh. The discovered coal is excellent in quality. The coals are bituminous and sub-bituminous with low sulfur and ash content. A heating value of 11,000 BTU/lb is reported.

There are five major coal fields in Bangladesh, namely, Jamaganj (Jaipurhat), Barapukuria (Dinajpur), Khalashpir (Rangpur), Dighipara (Dinajpur), and Phulbari (Dinajpur). A brief description of each field is discussed below.

4.7.3.1 Jamalganj Coal Field

Coal was discovered at Jamalganj in 1962. Estimated reserves are 1,470 million tons. Proved reserves are 1,054 million tons across 7 coal seams at depths ranging from 800 meters to 1,150 meters. At that depth, underground mining would not be economically viable. With the collaboration of expert foreign partners, coalbed methane extraction may be possible.

4.7.3.2 Barapukuria Coal Field

The Geological Survey of Bangladesh discovered high quality bituminous coal at Barapukuria in 1985. A techno economic feasibility study revealed estimated reserves of 390 million tons of coal in 6 seams at depths ranging from 130 meters to 500 meters. Considering the geological condition of the coals and the hydro geological system, Petrobangla decided to recover coal from only the No 6 Seam. Proved reserves of the No 6 Seam are 271 million tons. Recovery from this field is estimated to be 25 percent or 67 million tons of coal which is an energy equivalent of 1.77 TCF (Trillion Cubic Feet) of natural gas.

4.7.3.3 Khalashpir Coal Field

In 1989, an estimated 685 million tons of coal was discovered at Khalashpir at depths ranging from 257 meters to 483 meters. Proved reserves are estimated to be 143 million tons. Recoverable reserves are estimated to be 35 million tons of coal which is the energy equivalent of 0.92 TCF of natural gas.

4.7.3.4 Dighipara Coal Field

In 1995, Dighipara coal field was discovered at a depth of 250 meters. Estimated reserves are 200 million tons. Recoverable reserves are estimated to be 50 million tons of coal which is the energy equivalent of 1.31 TCF of natural gas.

4.7.3.5 Phulbari Coal Field

In 1997, coal was discovered at Phulbari at a depth ranging from 150 meters to 240 meters. Proved reserves are estimated to be 386 million tons. Open cast mining is under consideration and nearly 90 percent recovery is expected. That is the energy equivalent of 9.10 TCF of natural gas.

4.7.3.6 Coal Summary

The estimated recoverable reserves from all five fields are expected to be in the range of 724 million tons of coal which is the energy equivalent of 19.02 TCF of natural gas. Reserve estimates for each field are summarized in Table 4-4 below.

Table 4-4 Estimated, Proved, and Recoverable Coal Reserves

Coal Fields	**Estimated Reserves (million tons)**	**Proved Reserves (million tons)**	**Recoverable Reserves (million tons)**	**Energy Equivalent in TCF of Natural Gas (38 million tons of coal = 1 TCF gas)**
Jamalganj,	1,470	1,054	225	5.92
Barapukuria	390	303	67	1.77
Khalaspir	685	143	35	0.92
Dighipara	200	200	50	1.31
Phullbari	400	386	347	9.10
Total Coal	3,145	2,086	724	19.02
Gas Equivalent (TCF)	82.07	54.08	19.02	

Peat coal has also been discovered at the Khulna, Faridpur, and Madaripur areas at depths ranging from 1.75 meters to 4.25 meters. The heating value of the peat coal is around 6,370 BTU/lb which is about half the heating value of bituminous coal. There is an estimated 55 million tons of peat coal in Bangladesh which is the energy equivalent of 0.72 TCF of natural gas.

Experts opine that if all of the recoverable coal could be converted into power it could generate 20,000 MW of electricity for 66 to 90 years. Current technology used in the USA, Europe, Japan, and South Africa converts coal into clean synthetic liquid petroleum, synthetic gas, fertilizer, and other petrochemical products.

There are several challenges concerning the development of coal mines in Bangladesh. The first challenge is that the coal seams are very deep. The second challenge is that the coal seams are unusually thick. These problems make it very difficult for a poor country like Bangladesh to extract coal. These challenges require the development of coal in Bangladesh to be dependent on foreign energy companies.

The coal policy of Bangladesh will hopefully be finalized soon after proper consultation with experts and stakeholders has taken place. Bangladesh has very little funding, an unskilled workforce, and very little technology for coal development. Experts opine that extracting coal through open pit mining would ensure 80 to 90 percent extraction of the coal and this type of mining would pose less risk. Experts are in favor of at least 20 percent of power generation based on local coal. In Australia, 85 percent of the electricity is generated from coal. In China, 80 percent of the electricity is generated from coal. In India, 75 percent of the electricity is generated from coal. Currently in Bangladesh, 90 percent of the power generation is based on natural gas. Utilization of coal for electricity generation as an alternative to natural gas could be a viable option. Currently a 250 MW power plant is in operation at Barapukuria coal field where the extraction of 1 million tons of coal per year is planned.

For successful exploitation of coal, participation from the private sector with direct foreign investment is desirable. The terms for such private sector activity, including royalty rate, must be carefully chosen to balance both the Bangladesh national interest and financial goals of foreign investors.

Recently the Government has decided to set up a new company, Coal Power Generation Company of Bangladesh Ltd. The cost of power generation will decrease substantially once the company starts operating coal based power plants. The Government has set a target to generate 20,000 MW of power through coal-based power plants to run under the Power Development Board (PDB).

It is beyond the scope of the current project to model development of coal reserves and resources in Bangladesh. It would be appropriate for such a study to be conducted in order to assess the potential for coal to alleviate future energy shortages in Bangladesh, as well as the implications for emissions of carbon dioxide.

4.7.4 Liquefied Petroleum Gas (LPG) [53]

There is not a complete pipeline network infrastructure across the country, and furthermore gas resources are limited. In an effort to reduce deforestation and prevent pollution, the government has provided special incentives to help popularize the use of LPG. The government has reduced the tax rate on some spare parts of LPG bottles such as the pressure regulator/valve, the safety/relief valve, and the submerged welding flux.

Currently the country consumes around 96,000 metric tons of LPG per year, of which local production from the public sector is 22,500 metric tons and import from the private sector is 73,500 metric tons. Demand for LPG is increasing. The projected demand for LPG in the country is about 200,000 metric tons.

[53] This subsection is based on material from "Energy Scenario of Bangladesh", HCU, 2011

4.7.5 Petroleum Products

To meet the total demand of commercial energy, including new oil based power plants, last year Bangladesh imported about 5.4 million metric tons of petroleum products. Because of new diesel and furnace oil based power plants (expected 30 plants) in the present, (FY 2011-2012) petroleum import will be around 7.03 million tons; most of them will be in refined form. The lone refinery, Eastern Refinery Limited (ERL), a company of the Bangladesh Petroleum Corporation (BPC), is capable of processing 1.2 million metric tons of crude oil per year. Condensate is also extracted from different local gas fields. Approximately 0.35 million metric tons of condensate is being recovered from gas fields per year. To keep pace with the increasing demand for fuel, a feasibility study has been undertaken to examine an increase in the refining capacity of the Eastern Refinery Limited to 4 million tons through BMRE. In addition, a project for deep sea offloading facilities has also been initiated.[54]

4.7.6 Renewable Resources

Renewable energy resources could assist in the energy security of Bangladesh and could help reduce the natural gas demand. Regions of the country without supply or access to natural gas or the electric grid use biomass for cooking and solar power and wind for drying different grains and clothes. Biomass is currently the largest renewable energy resource in use due to its extensive noncommercial use, mainly for cooking and heating. Biomass comprises 38 percent of the total primary energy use in Bangladesh.

The country has a huge potential for generating solar power. Moreover the use of renewable energy has become popular worldwide in view of the depleting reserves of non-renewable fossil fuels. Renewable energy is environmentally friendly. The different sources of renewable energy that are being used in Bangladesh are outlined below.

[54] Source: Daily Prothom Alo, 14 September, 2011.

4.7.6.1 Biomass

Biomass refers to the organic materials produced from plants and animals. Examples of biomass are fuel, woods, leaves, agricultural residues, and animal dung. Converting biomass into more energy efficient fuel is a means of upgrading the rural energy consumption pattern. Biogas is very suitable for cooking and lighting (Mantel/Hazak) and for running a small generator to produce electricity. Throughout Bangladesh, there are currently about 50,000 households and village-level biogas plants in place. There is a real potential for harnessing basic biogas technology through rural electrification, village-level biogas production, and internal combustion (or even micro turbine) power generation.

4.7.6.2 Biofuel[55]

Biofuels can be produced from a variety of plants like rapeseed, mustard, corn, sunflower, canola algae, soybean, pulses, sugarcane, wheat, maize, and palm. The most popular option for producing bio-fuels is from non-edible oilseed bearing trees. The two most suitable species are: the Jamal gota (Jatropha curcas) and Verenda (Ricinus Communis). Both of these trees can grow virtually anywhere in any soil and geo- climatic condition.

The use of bio-fuel is increasing in most European countries. Germany has thousands of filling stations supplying bio-fuel and it is cheaper than petrol or diesel. The German government declared that 5 percent of every liter of fuel must be bio-fuel by 2010 and 10 percent of every liter of fuel must be bio-fuel by 2015. European Union (EU) countries are now capable of producing around 3 million metric tons of bio-fuel per year. Today EU countries are the pioneers in utilizing bio-fuel. It should be mentioned that all fossil fuel sold in France contains between 2 to 5 percent bio-fuel.

For the last 30 years, Brazil has been pursuing the production of ethanol from sugar cane resulting in an estimated saving of US $50 billion on oil imports as well as reducing

[55] This subsection is based on material from: "Bio Fuel & Bangladesh", Ahmed, N, Probe News Magazine, 2008 and Energy & Power magazine, 2008.

environmental pollution. In Brazil, sugar cane production is feasible because of favorable climate and large land area. In the USA the main source of bio-fuel is corn which is blended with gasoline in many states. Europe utilizes mainly rapeseed mustard biofuel feedstock.

Large scale bio-fuel investment is occurring in Australia, Brazil, India, Malaysia, and the USA. Malaysia opened its first biodiesel plant in December 2007, with a capacity of 100,000 tonnes per year.[56] By law all Brazilian petrol must be at least 25 percent ethanol. In Brazil, it was declared that by 2007, the majority of cars available must be able to run on 100 percent ethanol.

India is also giving proper attention to bio-fuel. One Indian Company in a joint venture with an international partner has installed a plant with a production capacity of 100,000-120,000 MT/year of bio-fuel.

Bio-fuel use is not new in Bangladesh. In the early 20th century, bio-fuel was used for lighting lamps or lanterns.

In an agriculturally based country like Bangladesh, bio-fuel can be a better alternative because a 30 percent blend of bio-fuel can be used along with our diesel or petrol. This can also be an excellent fuel to kindle lamps in rural Bangladesh.

Bio-fuel in Bangladesh can be a cost effective nontraditional approach. Attractive incentives should be offered to farmers who grow Jamal gota and Verenda and to the entrepreneurs investing in establishing processing units for refining crude bio-fuels into fuel grade bio-fuel. Barren lands in the hilly areas and fallow lands in the remote parts of the country may be used for bio-fuel projects.

For effective cultivation, around 2,500 plants can be planted in one hectare of land. The average yield of seeds per hectare per year is about 6 M tons. The cost for planting per hectare is estimated to be around Tk 50,000. It is quite possible to get a yield of more than 2,000 liters of oil from 1 acre of land planted with these types of trees.

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[56] http://en.wikipedia.org/wiki/Palm_oil#Biodiesel

Jamal gota or Verenda must be harvested, dried, and then crushed to produce oil. The oil can be used directly in any existing, unmodified simple diesel engine or processed through a process of refining or esterfication to produce bio-fuel that can be used in diesel run vehicles. Thus, in Bangladesh, significant quantities of bio-fuel could be produced to decrease the import of petroleum oil.

In Bangladesh, a non-edible source of bio-fuel (e.g. Jamal gota and Verenda) should be encouraged for large scale production. Large unused or degraded land areas in Rajshahi, Sylhet, Chitagong Hill Tracts, the Island in the South Bengal, and the Char areas of different rivers may be suitable for cultivating Jamal gota and Verenda.

4.7.6.3 Hydro-electricity

There is one hydro-electric power plant in Bangladesh, the Karnaphuli hydro-electric plant, built on the Karnaphuli River located at Kaptai. The power plant is operational and has a capacity of 230 MW. Geography and socio-economic conditions of the country may prohibit the expansion of hydro-electricity in Bangladesh. However, the possibility of installing mini and micro level hydroelectric power plants in the hilly areas of Bangladesh should be explored.

4.7.6.4 Solar Energy[57]

It is currently estimated that two billion people or roughly one third of the world's population are living without access to electricity. Many of these people live in countries whose governments are unable to afford the infrastructure development costs to extend the electricity grid beyond urban limits. In many cases, the rural population density is too low to justify economically viable grid installation. An obstacle to the wider use of solar energy is its high cost in comparison to other forms of power generation. It is uneconomic to extend electricity grids to remote areas. In remote areas, it is difficult to transport fossil fuels. This makes renewable

[57] This subsection is based on material at "Solar Energy: New Option" Ahmed, N: Probe News Magazine, 2006; and:"Solar Energy for the Buildings", Ahmed, N, Probe News Magazine, 2008.

sources like solar energy more attractive and cost competitive. Solar home systems are environmentally clean, user friendly, cost competitive, and reliable.

For these small remote populations, rural electrification can provide the cost effective means of providing electricity for basic needs. In such situations, electrification utilizing solar energy, the most important renewable form of energy, plays a very significant role.

In the past, there was not much use of solar energy for rural electrification. The related technologies often seemed unreliable, too costly, or incapable of providing enough power. Over the past few decades, renewable energy technology, particularly Photo Voltaic (PV) technology, has steadily improved and is now an acceptable energy source for remote power needs around the world.

Governments are politically, socially, and economically committed to the balanced development of their countries. A way to achieve this objective is by raising the standard of living in rural areas. Electrification with PV has been viewed as a viable solution by governments, NGOs, aid agencies, and other philanthropic organizations interested in raising rural living standards. PV is a low cost alternative used for lighting, ventilation, pumping water, and television in remote and dispersed communities.

The potential of solar energy is excellent in Bangladesh. Bangladesh is geographically located in a favorable position (within $20^{o}34'$ to $26^{o}38'$ north latitude) for harnessing bright sunlight. The sunlight is abundantly available for most of the year except for three months, June-August, when it rains excessively. The amount of solar energy available is about 5 KWh/day per square meter. That is enough to meet the demand of the country.

In 1997, Grameen Shakti and BRAC started the Solar Home System (SHS) using a credit incentive. The Rural Electrification Board (REB), a government agency, is also engaged in the commercialization of solar power electrification in domestic, commercial, and irrigation uses in rural areas. IDCOL, a government-owned entity, has disseminated some SHS through its partner NGOs. As a result of high costs of production, it has a long way to go before becoming commercially competitive. In remote areas of Bangladesh solar is gradually becoming popular and the government has undertaken a lot of schemes to subsidize on it. Presently there are about one million solar panels installed throughout the country. The government has planned to setup solar panels with a capacity of 5-10 MW.

The increased industrialization and urbanization of recent years has dramatically affected the number of urban buildings being built. The additional buildings have had major effects on energy consumption. The number of urban dwellers rose from 600 million in 1950 to 2.5 billion in 2010. It is predicted that by the mid 21st century, more than half of the world's population will be living in cities. It is widely accepted that urbanization leads to a very high increase in energy use. A recent analysis shows that a 1 percent increase in the per capita GNP leads to an similar (1.03 percent) increase in energy consumption. A 1 percent increase of the urban population increases energy consumption by 2.2 percent.

A home solar panel is a reliable source of alternative power that could supply part or all of home electricity needs. Solar panels produce clean energy and provide residences with a modern or high technology touch.

In Dhaka, the large scale use of solar panels on the roof tops should be considered to assist in resolving the power shortage issue.

The government of Bangladesh plans to substitute 5% of overall energy usage with solar energy by 2015 and 10% of overall energy usage by 2020.

4.7.6.5 Wind Energy[58]

Bangladesh is exploring the potential of wind power. In the coastal area of Bangladesh, windmills with a capacity of 2 MW are in operation. Bangladesh has had to wait for a breakthrough in wind power technology to be competitive against other conventional commercial energy sources. A pilot project to install windmills along the seashore with a

[58] This subsection is based on "Energy Scenario of Bangladesh" HCU, 2011

capacity of 20 MW has been planned by the government. Based on the results of the pilot project, another 200 MW of power could be harnessed from wind power.

4.7.7 Nuclear Energy[59]

As of 2005, there were 443 licensed nuclear power reactors in the world, of which, 441 are currently operating in 31 countries. Together they produce about 17 percent of the world's electric power.

Well-constructed nuclear plants run by enriched uranium are an advantageous source of electric power generation. They are extremely clean but improperly functioning plants can create potentially disastrous circumstances. The Chernobyl disaster and the recent Japanese Fukushima power plant disaster caused by a tsunami are examples of nuclear power plant related hazards. Bangladesh plans to establish its nuclear power plant with the assistance of international partners with proven experience, capacity, and willingness to transfer technology and ensure proper safety and security.

On June 24, 2007, the International Atomic Energy Agency (IAEA) gave approval for Bangladesh and seven other countries to set up nuclear reactors for power generation. This was good news because Bangladesh is currently exploring all possible options for resolving its power crisis. Currently, the power sector is based primarily on natural gas; nuclear energy would reduce future gas demand.

A plan to establish a nuclear power plant in Bangladesh has been in the works since the 1960s. Land selection and the acquisition of 260 acres for a nuclear power plant are the only tasks that have been realized over the last 50 years. Arrangements have been made by the Bangladesh government with the assistance of Russia to establish a nuclear power plant with a capacity of 1,000 MW at Ruppur. In this respect, the Bangladesh government has signed a framework

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[59] This subsection is based on "Nuclear Power in Bangladesh", Rahim A, Energy & Power, 2009; and "Nuclear Power Plant in Bangladesh", Ahmed, N, Probe News Magazine, 2007

agreement with the Russian National Nuclear Institute. Bangladesh expects to enter the nuclear age by establishing the nuclear power plant by 2016.

There are several challenges that Bangladesh must face involving the installation of a nuclear power plant. The safety of the population must be ensured, a knowledgeable workforce must be trained to administer and maintain the nuclear power plant, and general awareness of risks associated with a nuclear power plant must be administered to the public.

5 IMPACT OF TARIFF REFORM

5.1 HISTORICAL GAS TARIFFS

The first Bangladesh (then East Pakistan) gas tariff was announced in July 1968 by the government. The end user prices for gas for different categories of consumers specified in that tariff are shown in Table 5-1. The power and fertiliser sector had the lowest gas tariff, while the domestic and commercial sectors had the highest tariffs.

Table 5-1 Pre-Liberation Gas Tariff

Category of Consumer	Rupees/MCF
Power	1.20
Fertiliser	1.20
Industry	2.52
Commercial	6.00
Domestic (metered)	6.00

The tariff was the same for the power and fertiliser sectors. The price for commercial and domestic consumers was five times higher than the power and fertilizer prices. As the first tariff of the Bangladesh gas sector, it served as a basis for subsequent gas tariff revisions in Bangladesh.

After the independence of Bangladesh, gas tariffs were revised with different rates for different categories of consumers. During the 41 years from 1968 to 2009, the gas tariff was changed 25 times. The increase in price however, appears to be insignificant compared to the average inflation rate of 5% per annum, which exposes a significant gap with the price of energy.

The tariff rates in Table 5-2 show prominent changes from pre-liberalization tariffs rates that took place over the decades in the process of price harmonization.

Table 5-2 Current Gas Tariff (01/01/2010)

Category of Consumer	Taka/MCF	US $/MCF
Power	79.82	1.07
Fertiliser	72.92	0.98
Industry	165.92	2.22
Commercial	268.09	3.59
Domestic (metered)	146.25	1.96

The changes are described below:

a. The commercial sector tariff has the highest rate.

b. The tariff for the domestic sector increased, keeping pace with increases in other sectors.

c. A tariff for CNG (a new category) was added on 1st May 1992 with an initial tariff of Taka 43.05 /MCF (equal to the tariff for power). This tariff remained unchanged through five consecutive price revisions even though the gas price for the power sector went up to Taka 79.82/MCF. The rationale behind keeping CNG at a low tariff was to popularize the use of CNG in vehicles.

Revisions of the Gas Tariff are required to be approved by the Government and published in the official gazette. With the establishment of the Energy Regulatory Commission (ERC), the Gas Tariff revision proposal is examined, processed and notified by the ERC as per rules.

5.2 PROBLEMS DUE TO THE CURRENT GAS TARIFF

Currently, the gas tariff in Bangladesh is below economic levels. The tariff does not reflect all of the costs associated with developing, distributing, and transmitting gas in Bangladesh. The logic behind keeping the gas price low is to allow for a better quality of life for Bangladeshi citizens taking into account the general population's ability to pay for the gas.

Many problems arise from having a low gas tariff. The major problem with the low gas tariff is that it has left companies involved in the natural gas market in Bangladesh (namely Petrobangla) in an extremely poor financial state. The price that Petrobangla pays for gas purchased from IOCs exceeds the average price paid to Petrobangla by end users. While Petrobangla is providing the population with a low cost energy source, this approach is counterproductive and is not in the best interest of the general population. The financial drain on Petrobangla makes it much harder to develop any sort of reliable energy infrastructure in Bangladesh, to the detriment of all.

Table 5-3 shows Petrobangla's financial position between FY 1998 and FY 2008. Every year between FY 1998 and FY 2007 Petrobangla had a large net operating loss. Also every year in this range (excluding FY 2006) Petrobangla was forced to pay interest because they could not make timely payments for their gas.

Table 5-3 Petrobangla Deficits, Interest and IOC Income Tax Payments[60]

Fiscal Year	Operating Loss/(Profit)	Interest Expense	Income Tax	Previous Years Adjustment	Price Deficit Fund	Net Deficit
1998	-372.1	-4.9	0		832.2	455.2
1999	-2672.2	-37.6	0		1420.7	-1289.1
2000	-3901.5	-98.6	0		2694.4	-1305.7
2001	-5340.8	-104.2	0		3259.1	-2185.9
2002	-4113.4	-123.9	0		3707.6	-529.7
2003	-230.5	-71	-145.9		3854.6	3407.2
2004	-1750.8	-59.4	-1026.1	-707.9	4148.3	604.1
2005	-3817.9	-145.8	-584.9		4333.5	-215.1
2006	-2225.4	0	-1484.7		5316	1605.9
2007	-8150.4	-12.5	-1551.3		7113.4	-2600.8
2008	4323.18	-47.6	-3081.9		9542.2	10735.88
Total	-28251.82	-705.5	-7874.8	-707.9	46222	8681.98

***Tk. Million**

The gas tariff situation is also causing other problems in the economy. Due to the low gas price and the Model PSC 2008 requirement that all natural gas must be offered to Petrobangla, IOCs have limited incentive to explore for and produce natural gas in Bangladesh. The low gas tariff to end users is also causing the inefficient use of the resource in Bangladesh. This is especially true in the residential sector. Residential customers are charged a low fixed monthly price for

[60] Petrobangla Annual Report, 2009

gas regardless of the actual amount of gas consumed, so there is no incentive to use gas in an efficient manner.

5.3 GOALS FOR A REVISED GAS TARIFF

The Government considers the tariff as a tool for resource allocation, not a tool for revenue generation. While the current tariff is providing consumers with cheap gas in the short run, it is not allowing the energy sector to develop in Bangladesh. The main goals of revising the gas tariff will be to strengthen the financial position of Petrobangla, induce firms to explore and develop natural gas in Bangladesh, and prevent the wasteful use of the resource.

Raising the gas tariff would allow Petrobangla to cover its costs, allowing them to operate with a net profit, eliminating the price deficit fund and interest payments made to IOCs. The money saved from eliminating the deficit fund and interest payments could be used to fund projects to develop a reliable energy infrastructure in the country. With Petrobangla in a strong financial position, they will be able to induce IOCs to explore for and develop natural gas in Bangladesh. Through an optimal pricing strategy the gas tariff will be able to achieve other institutional and financial goals. A revised tariff will strengthen the mutual cooperation and assistance amongst various energy providers allowing for balanced growth and maintaining a reliable supply of gas.

The revised tariff will also help in reducing misuse/waste of the resource. Natural gas, being a non-renewable energy source is a scarce and costly resource. Misuse, waste, and unaccounted pilferage are rampant in Bangladesh. This requires adjustments to the pricing policy to prevent the inefficient use of the resource. Augmenting the gas tariff could assist in building a fund to pay for the import of LNG.

It is natural for consumers to resist price increases that are perceived as an arbitrary imposition of a burden. This resistance overlooks the underlying rationale with which political ramifications are usually involved. Public awareness about the overall energy situation will be necessary in the process of making any gas tariff increases.

5.4 GAS PRICING METHODOLOGY

Up to the 1980's revisions of the gas tariff took place on the principles of recovery of full cost plus margin for production, transmission, and distribution companies. In the 1990's the exploration margin was introduced to cover past and current exploration cost, both successful and unsuccessful. Since the start of production from IOCs' fields, the base of full cost has been expanded to include cost of gas purchases at the rate of 75% - 93% of the international market price of HSFO (capped by a ceiling that is currently binding) in addition to transmission and distribution cost.

The average gas tariff is estimated to cover the full cost, exploration margin, desired ROR on net fixed assets of production, transmission and distribution companies and government taxes. Thereafter, price harmonization is made for fixing different tariffs for different categories of consumers which all together will be equivalent to the required average gas tariff.

The prevailing gas tariff, though revised a number of times on an ad-hoc basis, is still substantially lower than IOC gas price, let alone the price for LNG. The ongoing and escalating gap between supply and demand may be moderated by revising gas tariffs at semi-annual intervals. This would allow gas consumers to adapt to the new gas tariffs gradually. Traditionally, the gas tariff encompasses different end user prices for different categories of consumers. In fixing such tariffs these steps must be taken:

The gas pricing methodology of the new proposed tariff will gradually address issues emerging from the growing complexities of transforming from the simple concept of 'cost plus recovery' to indexing with international fuel prices. The index to HSFO Singapore would tend to keep gas prices in line with other local energy prices, except that there is currently a binding price cap. The recent decision allowing Santos to sell gas directly from Block 16 to a third party may create issues concerning price harmonization between similar categories of consumers.

Petrobangla felt it necessary to link the gas tariff with an international market index to address the deficit that arises from purchasing IOC gas at a higher price than the average weighted gas tariff. Petrobangla intends to establish a pricing framework which will allow the gas tariff to be revised semi-annually based on the following criteria:

- The end user price of natural gas will be market based related to indexing with HSFO-FOB Singapore. Such a price for gas will be achieved gradually as a sudden increase would be disruptive.
- An automatic adjustment of prices as applicable to different categories of consumers will take place on a six month interval, linked to the market price of HSFO- FOB Singapore.
- Restructuring of current gas prices will be made for setting an economic price for each category of consumers.
- Government taxes on each unit of gas sold will be of a fixed amount to be determined, allowing Petrobangla to build a significant fund for its own investment.

5.5 SUMMARY

The current gas tariff in Bangladesh is too low and must be revised in order to develop the natural gas sector in Bangladesh. The gas tariff is causing significant problems in the country, most notably causing Petrobangla to operate at a significant deficit. Petrobangla has posted an operating loss in every year of the last decade except for 2008. Petrobangla's weak financial position (as depicted in Table 5-3) is significantly hampering its ability to develop a reliable energy infrastructure in Bangladesh. The low gas tariff is also hindering investment by IOCs in exploration and development activities, as well as promoting the misuse and waste of natural gas.

The ultimate goal of the government for revising the gas tariff will be for efficient resource allocation, rather than revenue generation. A higher tariff will strengthen Petrobangla's financial position allowing for investment in energy infrastructure, provide incentive for IOCs to explore for natural gas in the country, and raise consciousness about energy efficiency and misuse. The proposed tariff will be market related, indexed to HSFO-FOB Singapore. This tariff will keep gas prices in line with other local energy prices.

Increases in the gas tariff should occur in phased manner, as it would be disruptive to raise the tariff all at once. Tariff reform is of high importance for Bangladesh's energy sector and will benefit the general population in the long run by increasing the supply of natural gas.

6 PRIVATE SECTOR INVOLVEMENT AND PRIVATIZATION OF GAS BUSINESS

6.1 OVERVIEW OF THE PRIVATIZATION HISTORY IN BANGLADESH

Bangladesh faces a number of challenges in realizing its vision for the future development of the gas sector. The national companies that explore and develop natural gas in Bangladesh are totally owned by the government. These companies receive assistance from the Government through a price deficit fund. The price deficit fund is designed to offset the losses incurred when Petrobangla sells natural gas to end users at a lower price than it pays for the gas. Between the years 1998 and 2008 Petrobangla has received 46.2 billion Taka from the Government.[61] Every year during this date range (excluding 2008), Petrobangla has operated with a significant financial loss. One of the principal reasons for privatizing public enterprises in Bangladesh is to reduce the fiscal burden that their losses and their subsidization impose on the state.

"The privatization process in Bangladesh evolved gradually before taking concrete shape in 1993. The most significant move in the privatization process occurred in 1982 with the announcement of the New Industrial Policy. The Government introduced fundamental changes in the industrial policy environment and the adoption of various promotional measures designed to accelerate the pace of private sector-led industrial growth."[62] "In 1989, The Board of Investment was created, and serves to promote and facilitate investment in the private sector in Bangladesh."[63]

Along with production sharing contracts for oil and gas exploration both onshore and offshore in Bangladesh, the government may in the future allow open concession bidding for the construction and operation of new gas transmission and distribution pipelines. The new bidding system is to be regulated by an independent regulatory agency. This will facilitate increased efficiency in the gas sector.

[61] Gustavson Associates, Monitoring and Supervision Procedures for Exploration and Development Activities.
[62] Momen, M. N. Implementation of Privatization Policy: Lessons From Bangladesh (2007) Pg. 4.
[63] Momen, M. N. Implementation of Privatization Policy: Lessons From Bangladesh (2007) Pg. 4.

6.2 PETROBANGLA'S CURRENT ROLE IN THE GAS SECTOR

Petrobangla can be thought of as a gas merchant, as they are the primary buyer of natural gas in Bangladesh, buying directly from the IOCs and directly transmitting and selling the gas to end users. Under the current PSC (Model PSC 2008), Petrobangla has the right of first refusal which requires the contractor to first offer its gas to Petrobangla. If Petrobangla refuses to buy the gas from the IOCs, they must make alternative arrangements for sale in the domestic market. The IOCs are required to sell the gas in the domestic market due to severe restrictions in the PSC that do not allow piped gas to leave the country. Only gas which is converted to LNG is allowed to be exported. This option however is not economically viable to IOCs operating in Bangladesh, due to the large capital investment involved in building LNG plants and the requirements of large reserve commitments.

This arrangement is causing significant difficulties for Petrobangla and IOCs alike. Petrobangla is buying gas produced by IOCs at a higher price than they are selling to end users. This is causing Petrobangla to operate at a significant financial loss, some of which is offset by the government contributing to a price deficit fund.

IOCs may be hesitant to explore for and develop natural gas in Bangladesh because of the harsh terms, particularly the low pricing, defined in the PSC. The natural gas infrastructure in Bangladesh is very weak, and the market is not well established. Also, the transmission system is wholly owned by Petrobangla and its subsidiaries. If IOCs are not confident that they will be able to find a reliable buyer for their gas as well as receive an adequate price, they may take their investments elsewhere.

6.3 ALTERNATIVE ROLES FOR PETROBANGLA

Petrobangla has options that could alleviate some of the problems in the gas sector. Instead of acting as a gas merchant, Petrobangla could assume the role of a gas transporter. As a gas transporter, Petrobangla would be responsible for maintaining the gas supply network, transporting gas through their pipelines to end users for an agreed upon tariff.

This arrangement could be mutually beneficial for Petrobangla and the IOCs. As a gas transporter, Petrobangla would be able to eliminate large payments to the IOCs for the purchase of gas. Petrobangla has been plagued in the last 20 years by not being able to make timely payments for IOC gas, which has resulted in hefty interest payments. By eliminating the need for gas payments to the IOCs, Petrobangla will have a much better financial position and also eliminate its interest payments. The increased revenue created by this arrangement could be used to develop the gas infrastructure which is in its infancy in Bangladesh, as well as induce new firms to explore and develop natural gas in Bangladesh.

Santos Bangladesh (one of the principal IOCs currently operating in Bangladesh), has suggested that Santos be allowed to sell gas directly to a third party, paying a tariff to Petrobangla for using their transportation network. This concept would allow free competition between buyers and sellers that would lead to the efficient market price for natural gas. This would benefit the IOCs with a higher sales price than they would get under the current arrangement, as well as entice further investment by IOCs in Bangladesh's gas sector.

Petrobangla's transmission and distribution companies may find it beneficial to allow their pipelines to become common carriers. Currently the transmission and distribution network in Bangladesh is wholly owned and operated for exclusive use by Petrobangla. A common carrier system would modify Petrobangla's role as a gas merchant, into a natural gas carrier. Through this system Petrobangla would own and operate the entire pipeline network; however they would be required to offer transport services to any natural gas shippers at a fixed rate.

The transition to a common carrier system could allow the market to adequately distribute the supply of natural gas in Bangladesh. Currently Petrobangla owns all the production, transmission, and distribution rights in Bangladesh. Petrobangla monopolizes this industry in Bangladesh, as potential entrants into the market are hindered by the inability to access the distribution network. Separating the gas production, transmission, and distribution business to new entrants through a common carrier system would improve economic efficiency through increased competition and lower costs.

6.4 SUMMARY

Bangladesh is on its way to enhancing efficiency in the gas sector through privatization.[64] Privatization is being pursued because Petrobangla, a State Owned Enterprise (SOE) has become a burden on the state from operating at a significant financial loss. Due to the fact that Petrobangla sells gas at a cheaper price than they buy it for, the government must contribute to a price deficit fund to keep Petrobangla afloat. This price deficit fund could be used to make enhancements in the country's energy infrastructure. Privatization of the gas sector may also enhance economic growth and employment in Bangladesh.

Petrobangla currently operates as a gas merchant, buying gas from IOCs and selling it directly to end users. Gas tariffs in Bangladesh are far below international energy prices, a policy the government has enacted to provide affordable energy to the general public. This policy however has put Petrobangla in an extremely poor financial state, as they buy gas for more than they sell it to end users. Petrobangla's poor financial situation has made timely payments for natural gas impossible, resulting in large interest payments.

Petrobangla should consider an alternative role as a gas transporter. As a gas transporter Petrobangla would transport a third party's gas across its distribution network for an agreed upon fixed price. In this way Petrobangla could stabilize its financial position by eliminating the need to buy gas from IOCs, thereby also eliminating its interest payments. Santos Bangladesh supports this idea; they want the flexibility to sell gas directly to a 3rd party. Introducing Petrobangla as a gas transporter through a proposed common carrier system will promote free competition between buyers and sellers and allow the market to efficiently allocate the supply of natural gas in Bangladesh.

[64] http://boi.gov.bd/about-bangladesh/privatization

7 GAS SUPPLY SCENARIOS IN BANGLADESH

7.1 OVERVIEW

Gustavson Associates has prepared a computer model for forecasting future gas demand and supply for the country of Bangladesh. The model includes forecasts for various categories of reserves and resources, as follows:

- Existing fields
- Mapped prospects
- Mapped leads
- Unmapped resources
- CBM
- Shale gas

The volumes of reserves and resources have been estimated previously by Gustavson. The forecasts are probabilistic, considering uncertainty about reserves, production rates, decline rates, rates of exploration drilling, and probabilities of success for all of the resource categories. Six scenarios have been modeled: two exploration timing assumptions for each of three demand scenarios. The three demand scenarios are a base case as well as high and low growth demand cases. The two exploration scenarios are a base case and an accelerated case in which exploration activity for prospects and leads is assumed to occur earlier in time. Table 7-1 and Table 7-2 summarize the findings of the six different scenarios.

Table 7-1 Summary of the supply scenarios with the realistic exploration timeline

	Normal Exploration Timeline		
Demand Growth Scenario	**Early Years (2011-2015)**	**Intermed. Years (2016-2023)**	**Late Years (2024-2030)**
High	shortage of about 0.3 BCFD is likely	almost no chance of sufficient domestic gas to meet demand	almost no chance of sufficient domestic gas to meet demand
Base Case	small shortages (~ 0.2 BCFD) likely	shortages of 1.5 BCFD to 3 BCFD almost certain	>10% chance of sufficient domestic gas supply. 50% chance there will be a shortage of 4 BCFD or more
Low	sporadic small shortages are likely	shortage is almost guaranteed	>10% chance of sufficient domestic gas supply

Table 7-2 Summary of the supply scenarios with the accelerated exploration timeline

	Accelerated Exploration Timeline		
Demand Growth Scenario	**Early Years (2011-2015)**	**Intermed. Years (2016-2023)**	**Late Years (2024-2030)**
High	small shortage of about 0.1 BCFD is likely	>10% chance of sufficient domestic gas to meet demand	>10% chance of sufficient domestic gas to meet demand
Base Case	small shortage of about 0.1 BCFD is likely	50% chance of sufficient domestic gas to meet demand	>10% chance of sufficient domestic gas supply. 50% chance there will be a shortage of 2 BCFD or more
Low	sporadic small shortages are likely	>50% chance of sufficient domestic gas to meet demand	>50% chance of sufficient domestic gas to meet demand

In each of the scenarios, it is highly unlikely there will be an sufficient domestic supply of gas throughout the next twenty years. It is very possible there will be small shortages through 2015 and almost certain there will be large supply shortages in the intermediate years of 2016 through 2023. In most of the scenarios, there is a low probability of sufficient gas supply in the late years. Details of the model and scenarios are discussed below.

7.2 ASSUMPTIONS

The following assumptions were made in preparing the supply forecasts:

1. The initial rate for the existing fields was based on an average of recent production rates.
2. For each field, a random variable was set up for the percentage of reserves produced at which production decline will begin. Prior to that percentage, production per well was assumed to remain flat. The distribution for the random variable was set to a uniform distribution between 35% and 73%. The 35% figure was based on judgment, while the 73% represents the highest percentage recovery from producing fields where decline has not yet begun.
3. The decline, when it begins, was assumed to be exponential with a decline rate based on the production in the last plateau year as a percentage of the reserves in that year.
4. There are some scenarios in which exploration success leads to excess gas availability. In the event that the forecast demand is lower than the total forecast deliverability of supply, the

production from each type of source is uniformly scaled back by a factor equal to the demand divided by the deliverability.

5. The decline is applied as a fraction of reserves in order to account for reduced decline if production is scaled back due to limited demand.
6. The reserves uncertainty for each field is represented by a log normal distribution with P_{90} (low), P_{50} (mid), and P_{10} (high) as estimated in Gustavson's prior reserve estimation. It may be necessary to install additional compression at the fields in order to achieve the high values. Due to the high cost of compression, there is uncertainty about whether it will be installed.
7. Additional drilling in existing fields as projected by Petrobangla[65] is accounted for in the forecasts (see Table 7-3).
8. New wells are assumed to come online at the current average rate of other wells producing in each field.

Table 7-3 Schedule of New Wells for Producing Fields

	Fiscal Year					
Field	**2011**	**2012**	**2013**	**2014**	**2015**	**Total**
Bakhrabad	0	0	1	0	0	**1**
Bibiyana	0	4	0	2	1	**7**
Fenchuganj	1	0	0	0	0	**0**
Jalalabad	0	0	0	1	0	**1**
Kailash Tila	0	0	0	3	1	**4**
Moulavi Bazar	0	1	0	1	0	**2**
Rashidpur	0	2	0	3	2	**7**
Salda Nadi	1	1	1	0	0	**2**
Shahbazpur	0	2	0	0	0	**2**
Sylhet	0	0	2	0	1	**3**
Titas	0	2	0	3	2	**7**
Total	**2**	**12**	**4**	**13**	**7**	**36**

9. For the six discovered fields not currently producing (Chhatak, Feni, Kamta, Begumganj, Kutubdia, and Semutang), all except Semutang were assumed to begin producing in July 2016. Semutang was assumed to begin producing in July 2011 per Petrobangla plans.[66]

[65] From "Energy Division LCG meeting 110411.ppt"
[66] From "Energy Division LCG meeting 110411.ppt" page 11.

10. The currently non-producing fields were assumed to require a certain amount of time to complete development and achieve their peak rate. A random variable was used to estimate the fraction of reserves produced at the time peak rate will be achieved, based on analysis of the distribution of recovery at peak rate for the currently producing fields.
11. The peak rate for each currently non-producing field was assumed to be equal to the ratio of that field's reserves to the original reserves of Bibiyana Field, multiplied by the peak rate at Bibiyana.
12. Total well count by year for the currently non-producing fields was based on the average well count per MMCF of annual production for the producing fields multiplied by the annual production for that year, rounded up to the next whole number.
13. The category of Awarded Blocks, for the purposes of this report, consists of blocks 8 and 11 held by Bapex and block 7 held by Chevron.
14. The category of Unawarded Blocks, for the purposes of this report, consists of all other blocks not held by production.
15. Exploration drilling of the mapped prospects was assumed to begin in August 2013.
16. The amount of time between exploration wells was assumed to be a random variable with an exponential distribution and a mean of one year.
17. Each mapped prospect was modeled with the mean and standard deviation equal to that of all the mapped prospects in the appropriate area (whether in the eastern foldbelt or outside the eastern foldbelt and on awarded or unawarded blocks). These values were derived from Gustavson's resource report.
18. The probability of success of the mapped prospects as discussed in Gustavson's resource report was applied to each prospect.
19. For mapped prospects, the ramp up, peak rate, decline, and well count for the successful mapped prospects were modeled in the same manner as the not currently producing fields as described above.
20. Exploration drilling of mapped leads was assumed to begin in August 2015.
21. For mapped leads, the time between exploration wells, probability of success, ramp up, peak rate, decline, and well count for the successful mapped leads were modeled in the same manner as the mapped prospects as described above.

22. The start of exploration drilling for unmapped conventional resources was assumed to delayed until August 2025, since other better defined prospects would be explored first.
23. For unmapped conventional resources, the time between exploration wells, probability of success, ramp up, peak rate, decline, and well count for the successful unmapped targets were modeled in the same manner as the mapped prospects as described above. The resource sizes were based on the probability approach used in the USGS report, which identified six assessment units. The present model uses the USGS probability distribution for each assessment unit, and the mean number of targets within each to estimate the relative frequency of target exploration.
24. Exploration drilling for coal bed methane (CBM) resources was also assumed to begin in August 2013.
25. For CBM resources, the time between exploration wells, probability of success, ramp up, peak rate, decline, and well count for the successful CBM targets were modeled in the same manner as the mapped prospects as described above, with the exception that the peak rate per well for calculation of well count was assumed to be 500 MCF per day. Five CBM targets were modeled with a probability of success of 41% for each target.
26. Exploration drilling for shale gas resources was assumed to begin in August 2016.
27. For shale gas resources, the time between exploration wells, probability of success, ramp up, peak rate, decline, and well count for the successful shale gas targets were modeled in the same manner as the mapped prospects as described above, with the exception that the peak rate per well for calculation of well count was assumed to be 4 MMCF per day. Four shale gas targets were modeled with each having a probability of success of 4%.

7.3 BASE CASE

The supply model is a Monte Carlo model that incorporates uncertainty about all supply sources. There is some uncertainty about supply from existing fields, but more uncertainty about the supply from other sources such as leads and prospects. A base case model was run with a realistic timeline for exploration of the various resource categories. It was assumed that exploration wells for prospects and leads would be drilled in blocks that have been awarded first, then blocks in the eastern foldbelt, followed by the remaining blocks.

Table 7-4 lists the assumptions for the date to drill the first exploration well in each of the resource categories.

Table 7-4 Timeline of first exploration wells for base case

Date of First Exploration Well	Prospect	Lead
Awarded Blocks	8/1/2013	8/1/2015
Eastern foldbelt, unawarded	8/1/2017	8/1/2020
Other, unawarded	8/1/2019	8/1/2025
	Target	
CBM	8/1/2013	
Shale Gas	8/1/2016	
Unmapped	8/1/2025	

Figure 7-1 shows the results of the Monte Carlo model for the base case (intermediate) demand forecast. There is a 10% chance that production will exceed the P10 curve, and a 10% chance that it will be below the P90 curve. The production is equally likely to be above or below the P50 curve. The figure illustrates the high likelihood of domestic gas shortages in the future, given the assumptions about the timing of future exploration. The figure shows annual averages, and does not consider short term or seasonal fluctuations in supply and demand. Such short term or seasonal fluctuations may lead to temporary shortages, which are not modeled. The figure shows the demand curve as well as possible twenty year production profiles.

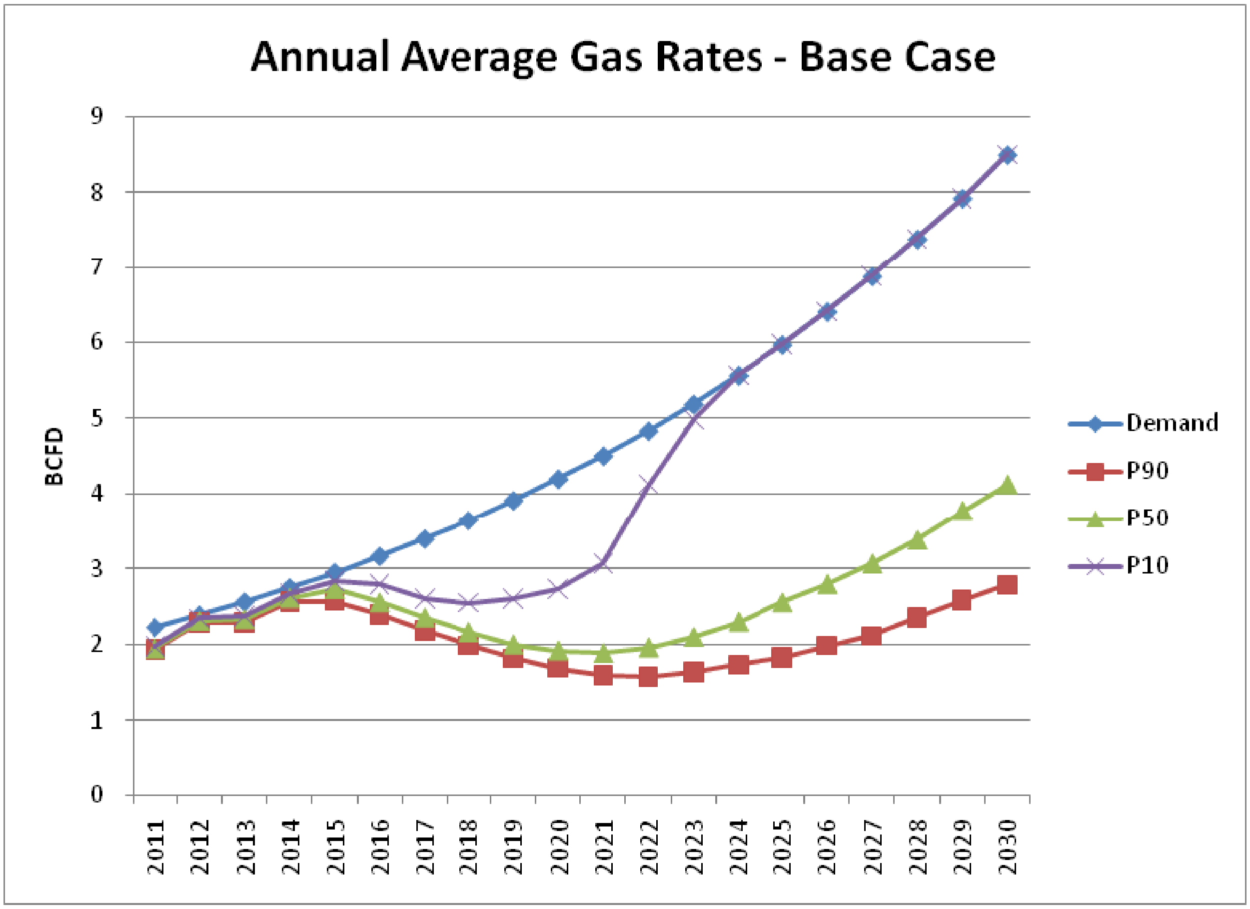

Figure 7-1 Base Case - Annual average gas rate

The figure illustrates that there are three time periods of interest. In the short term (through about 2015), it is highly likely that there will be almost enough gas to meet demand, although small gas shortages will occur. In the intermediate years, 2016 through 2023, there will almost certainly be an insufficient domestic supply of gas to meet demand. In this period, production from existing fields declines, as can be seen in Figure 7-2. Figure 7-2 shows one production forecast scenario for the existing fields. In this scenario the production rate increases as new wells are drilled in existing fields until 2015 when the peak rate is reached. Thereafter the production from the existing fields is predicted to decline throughout the remaining life. There is some uncertainty about gas production from existing fields. The figure shows one possible scenario. The model considers a range of possible outcomes.

Figure 7-1 shows that in the late years (after 2023) there is at least a 10% chance that enough gas will be produced to meet demand. However there is a 50% chance that domestic supplies will fall short of demand by about 3 BCFD or more. The gas supply may increase in the long term as new fields begin to come online, but there is a low probability that these new fields will provide enough gas to meet the domestic gas demand in the later years. Alternative sources of energy, such as LNG and coal, should be considered to alleviate the anticipated domestic gas supply shortages.

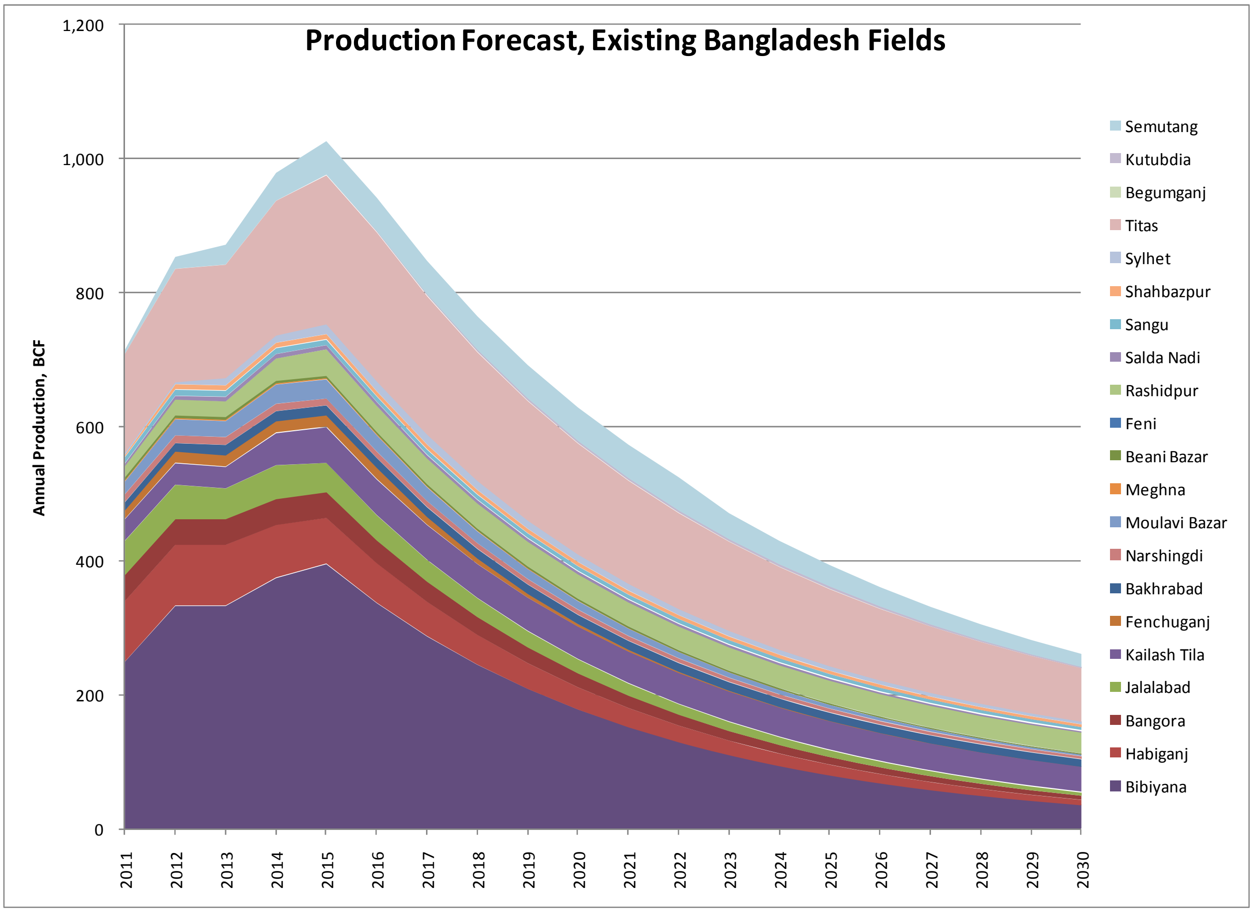

Figure 7-2 A Production Scenario for the Existing Fields

There are many possible future supply scenarios depending on the number and timing of gas discoveries that are made. Figure 7-3, Figure 7-4, and Figure 7-5 illustrate three possible types of scenario for gas supply and demand in Bangladesh predicted by the model. In all of the scenarios, a small gas supply shortage is forecast to occur in the short term (through 2015). Figure 7-3 shows a significant supply shortage of up to 3 BCFD or more in the intermediate years as very few supply sources other than the existing fields come online. Even though more prospects and leads come online in the later years, the domestic supply of gas falls short of demand by up to 5 BCFD or more as demand increases.

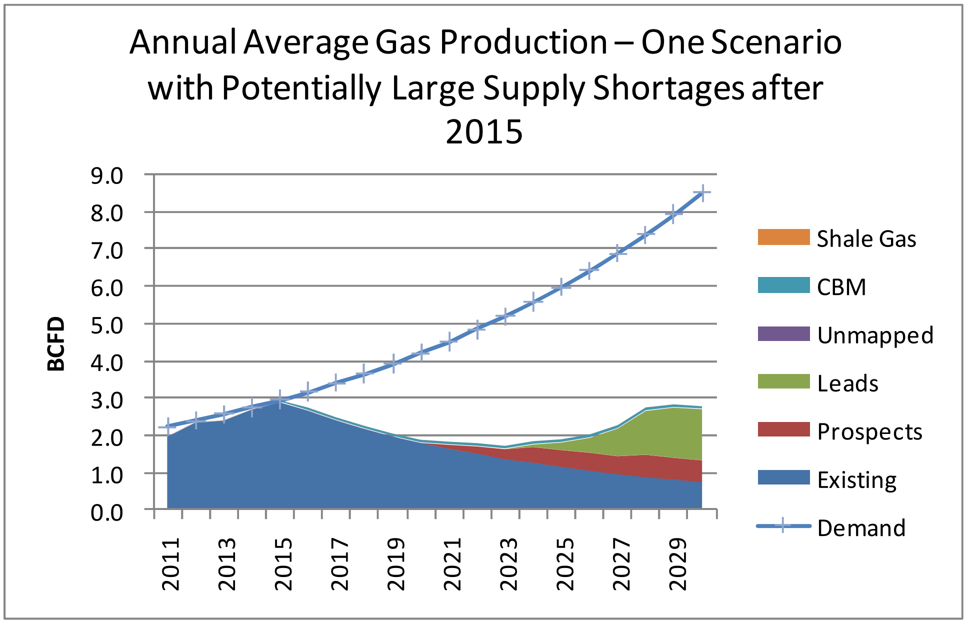

Figure 7-3 Scenario with significant domestic gas supply shortages

Figure 7-4 illustrates a scenario in which prospects and leads begin to come online earlier than in Figure 7-3 as the results of earlier and larger discoveries. Domestic supply is still insufficient to meet demand in the intermediate years and in the long term. But the shortage is reduced to between 2 and 3 BCFD.

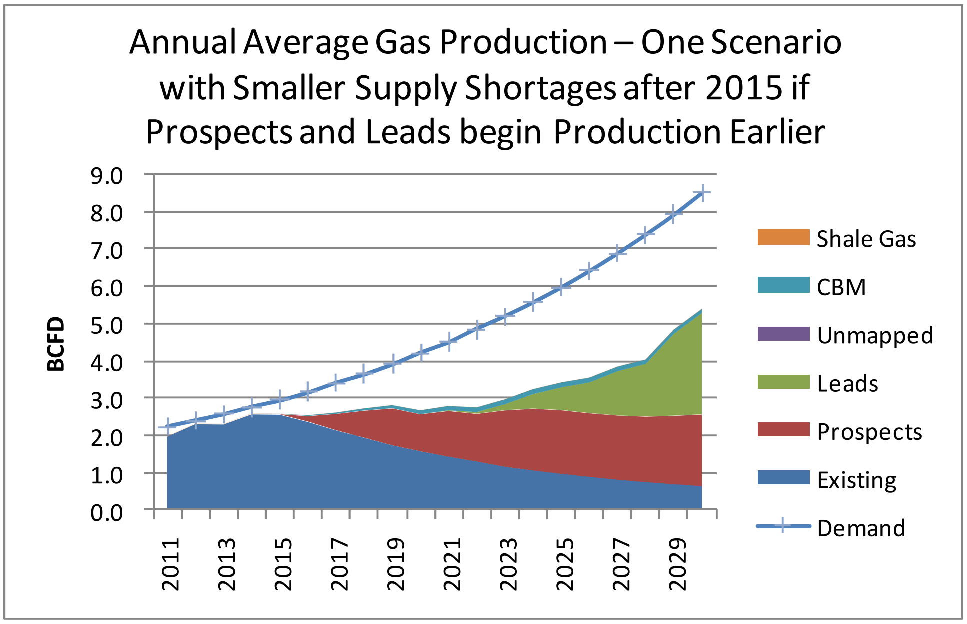

Figure 7-4 A scenario with shortages, but growing domestic gas supplies

Figure 7-5 shows another potential base case scenario in which significant shale gas discoveries are made. This could eliminate the gas supply shortage in the late years. In this scenario the largest supply shortage occurs in the intermediate years and is approximately 1.5 BCFD.

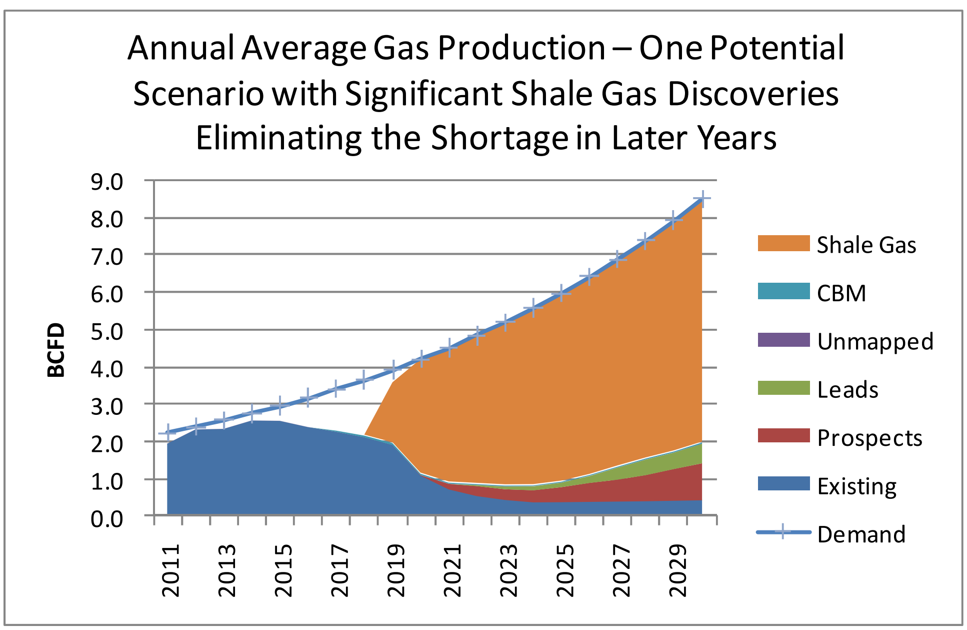

Figure 7-5 A base case scenario with substantial shale gas discoveries

The three previous figures show some possible scenarios, but there are many other possibilities. Table 7-5 shows three percentiles for gas production from each gas source over the next twenty years. The table shows that existing fields are likely to provide the bulk of production over the next twenty years, but there is a small chance of substantial shale gas production. We have modeled four regions each with an independent 4% chance of shale gas discoveries. This implies that there is only a 15% chance of at least one shale gas discovery.[67] Under the base case timing assumptions, the first possible year of shale gas production is 2018. Although shale gas has the potential to provide significant amounts of gas supply in Bangladesh, it has a low probability of doing so. Significant exploration activity would be required, but the effort seems worthwhile given the large potential upside.

Table 7-5 Gas production over next 20 years

BCF	P90	P50	P10
Existing	11,333	12,149	12,816
Prospects	1,471	3,212	5,958
Leads	675	1,983	3,861
Unmapped	-	-	4
CBM	-	-	211
Shale Gas	-	-	12,285
Total[68]	**15,727**	**18,475**	**30,271**

Figure 7-6 depicts the mean (average) gas production forecast over twenty years with the base case demand scenario, broken down by the different gas sources. Existing fields are forecast to make up most of the production in the early and intermediate years. The mapped prospects and leads will probably generate the bulk of production in the late years. Coalbed methane and shale gas have a small chance of a large contribution to production in the late years. The unmapped targets will likely have no impact in the next twenty years due to assumed delays in exploration. The mapped prospects and leads are assumed to be targeted first.

[67] Probability of no shale gas discoveries = $(1-0.04)^4 = 0.85$. Probability of some shale gas discovery = 1 – 0.85 = 0.15.

[68] The P90, P50 and P10 in each category do not add up to the total because of statistical independence.

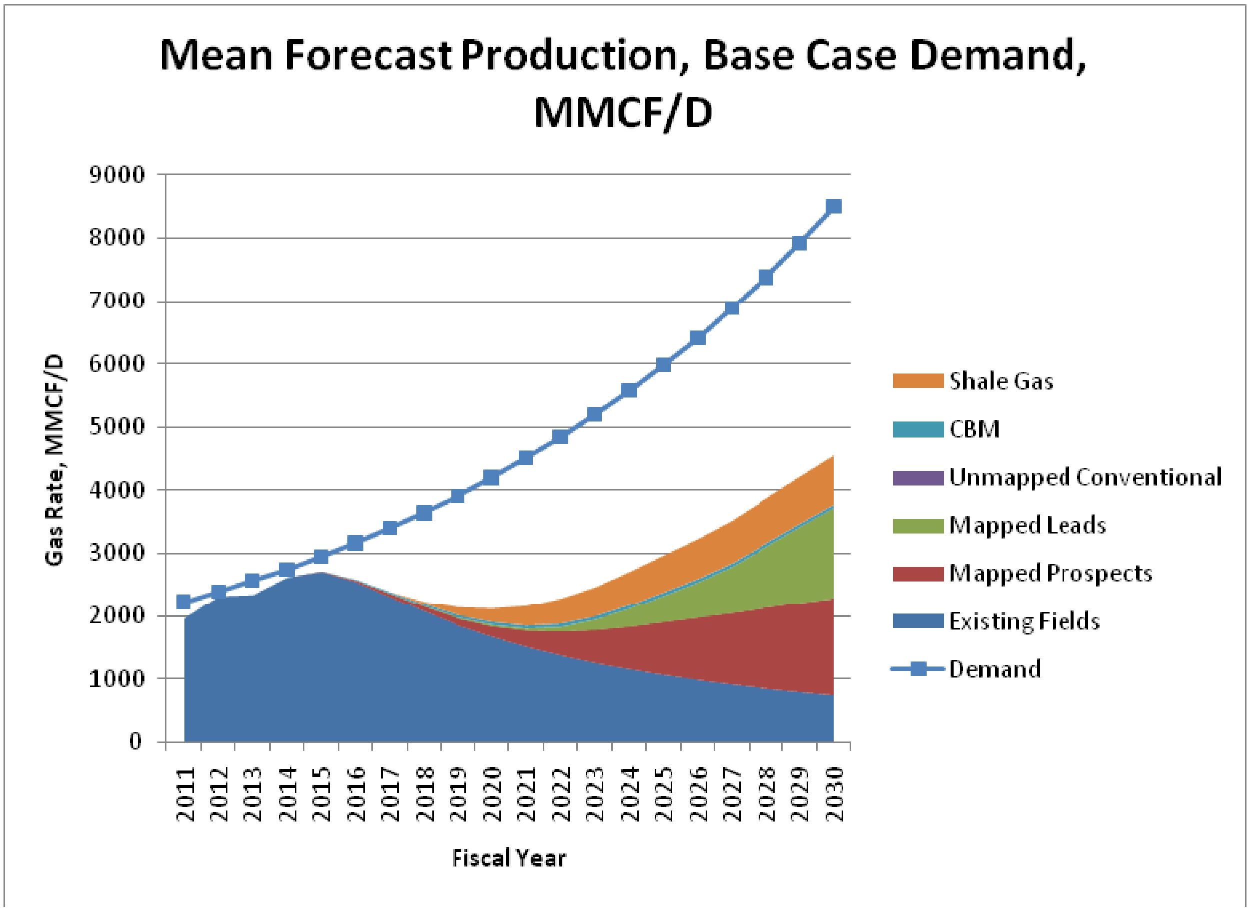

Figure 7-6 Base Case - Mean Gas Production

7.4 ACCELERATED BASE CASE

One possible approach for alleviation of potential gas shortages is to accelerate exploration activity. A second base case model was run assuming an accelerated timeline for the prospects and leads, with the first prospect and lead exploration wells being drilled in January 2012. This is an unrealistically aggressive assumption, but it demonstrates how an accelerated exploration schedule could alleviate gas supply concerns in Bangladesh. Table 7-6 lists the assumed accelerated timeline for prospects and leads.

Table 7-6 Timeline of first exploration wells for accelerated base case

Date of First Exploration Well	Prospect	Lead
Awarded Blocks	1/1/2012	1/1/2012
Eastern foldbelt, unawarded	1/1/2012	1/1/2012
Other, unawarded	1/1/2012	1/1/2012
	Target	
CBM	8/1/2013	
Shale Gas	8/1/2016	
Unmapped	8/1/2025	

Figure 7-7 shows that there is about a 50% chance that gas supply will be able to meet demand through 2023 under this accelerated exploration schedule, although small shortages are predicted for fiscal year 2011.

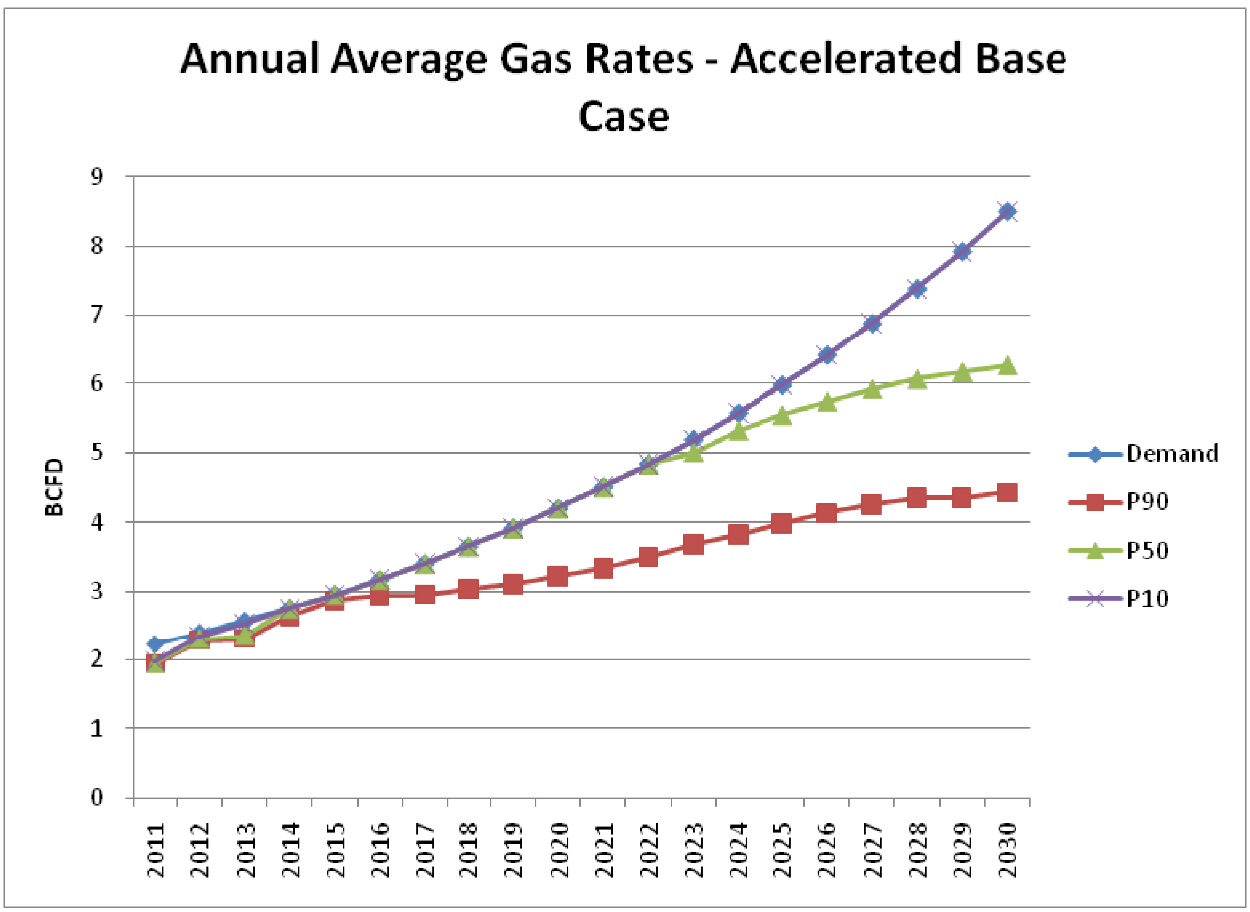

Figure 7-7 Base Case with Accelerated Exploration

Figure 7-8, Figure 7-9, and Figure 7-10 show three potential scenarios for the accelerated base case model. In all of these scenarios, a small gas supply shortage is predicted to occur in the short term (through 2015). The scenario in Figure 7-8 shows a small shortage of gas of up to 1.5 BCFD in the intermediate years. The shortage doubles in the late years to 3 BCFD as exploration and development activity does not keep pace with gas demand.

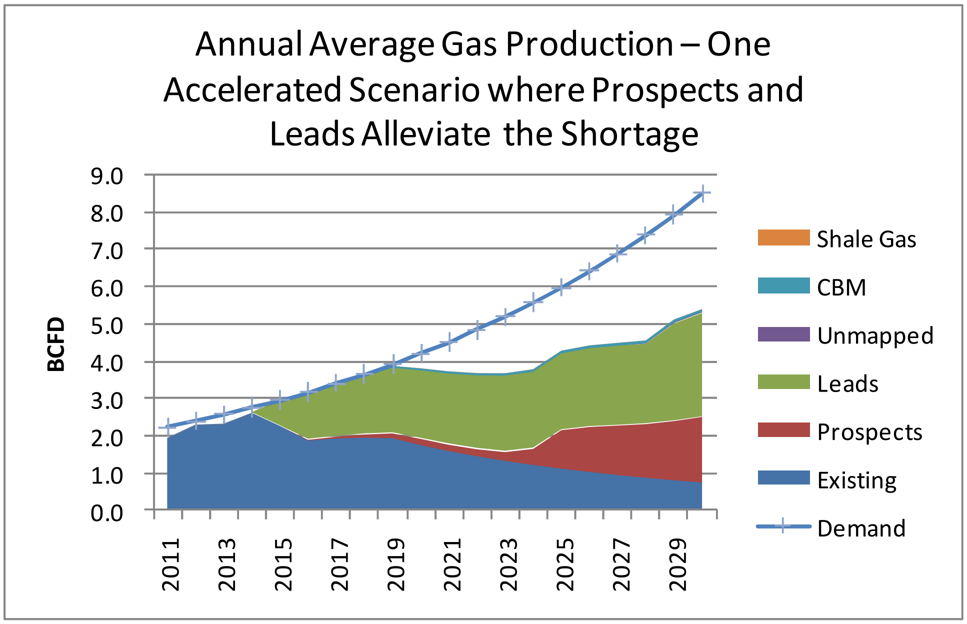

Figure 7-8 An accelerated base case scenario with delayed shortages

Figure 7-9 depicts an accelerated base case scenario in which exploration success with prospects and leads enables supply to meet demand in the intermediate years. A small shortage would arise in 2024 and increase thereafter.

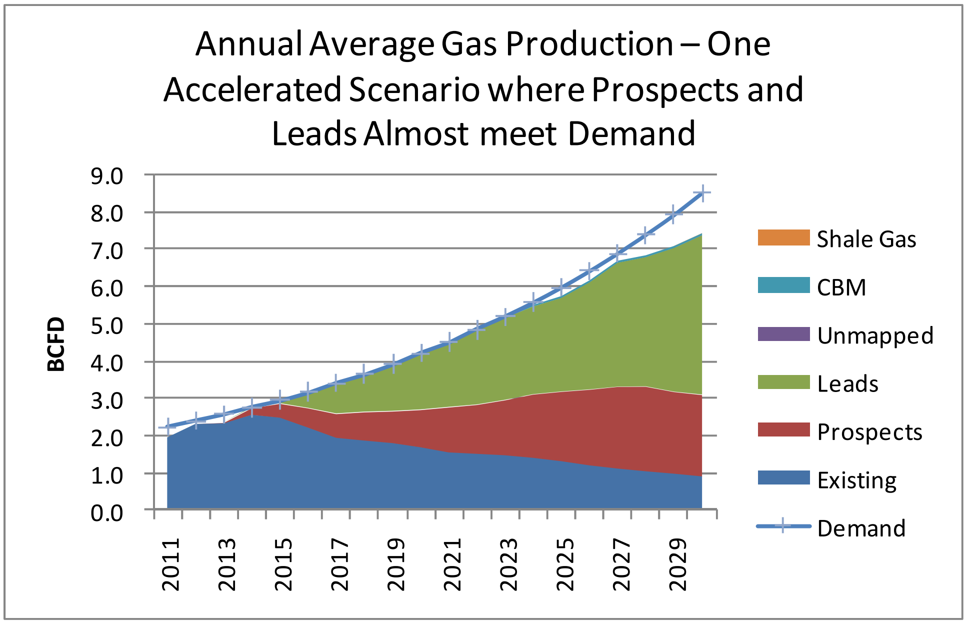

Figure 7-9 An accelerated base case scenario with sufficient gas for 15 years

Figure 7-10 illustrates another accelerated base case scenario in which a significant amount of shale gas is discovered. This enables domestic supply to meet demand until 2026.

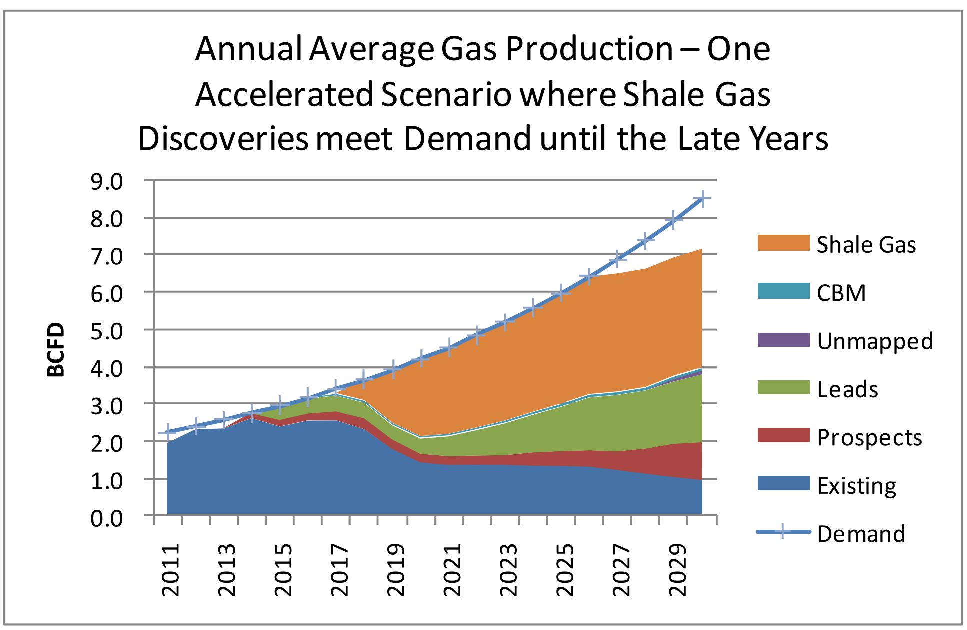

Figure 7-10 An accelerated base case scenario with substantial shale gas

Table 7-7 separates the production over the next twenty years by resource category into the P90, P50 and P10 while Figure 7-11 illustrates the potential breakdown by resource category of the mean production in the next twenty years with the accelerated base case. Existing fields will likely hold the majority of production in the early years. Mapped prospects and leads will likely contribute the most production in the intermediate and late years, with coalbed methane and shale gas each contributing a small amount. Like the base case, the unmapped targets will likely not contribute to production in the next twenty years.

Table 7-7 Gas production over next 20 years – Accelerated base case

BCF	P90	P50	P10
Existing	10,465	11,861	12,543
Prospects	3,656	6,931	10,335
Leads	4,696	9,467	14,283
Unmapped	-	-	4
CBM	-	-	202
Shale Gas	-	-	10,970
Total[69]	**24,745**	**30,854**	**34,126**

A comparison of Table 7-5 and Table 7-7 shows that accelerated exploration of prospects and leads could lead to a large increase in Bangladeshi gas production over the next twenty years. The median (P50) country-wide production is predicted to increase by about 12.4 TCF from about 18.5 TCF to about 30.9 TCF. The bulk of the increase (about 7.5 TCF) is predicted to come from leads that are explored and developed. Prospects are predicted to add about 3.7 TCF of gas production over the twenty year period. The median 20-year production from existing fields is predicted to decrease slightly, as production from new fields displaces that from existing fields.

Table 7-7 illustrates a striking benefit that arises from the multiplicity of potential gas sources in Bangladesh. The sum of the P10 gas production values from all of the potential sources is much larger than the P10 of the total gas production. This is not a mistake. The total gas production will not exceed the gas demand. So the P10 for total production is bounded above by demand. However, the 20-year production from any individual type of gas supply can be large, if the

[69] The P90, P50 and P10 in each category do not add up to the total because of statistical independence.

supply from other sources is significantly lower than demand. In other words, there is a small probability of large quantities of gas production from each of the potential sources, although because of demand limitations, there will not be simultaneously large production from multiple sources. Simply put, the presence of several potentially large sources of gas reduces the chance of large shortages in the domestic supply of gas, if exploration activity for conventional gas sources can be accelerated. This can also be seen in Figure 7-7, which shows that there is at least a 10% chance of no gas shortages over the twenty year forecast period, with the accelerated exploration timeline.

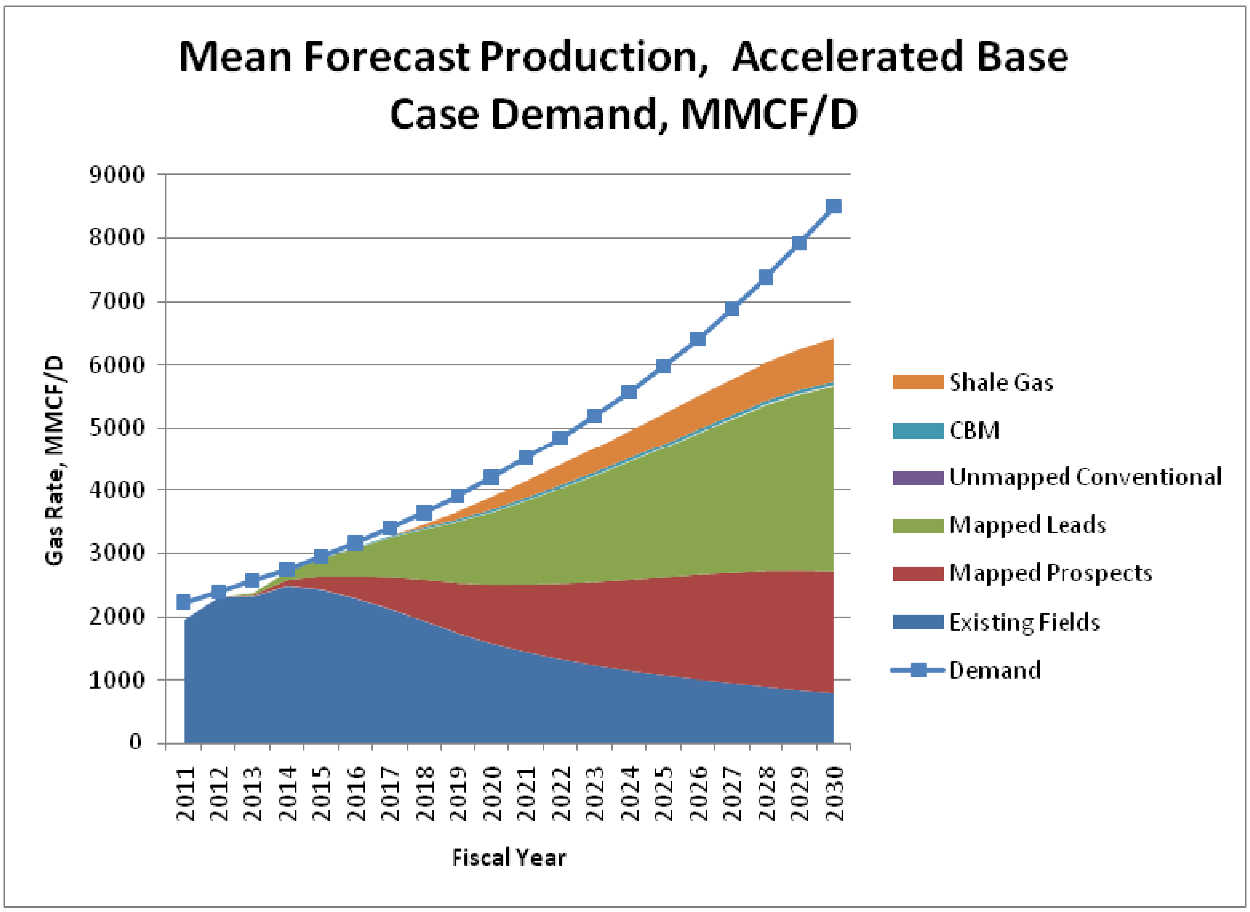

Figure 7-11 Mean gas production - Accelerated base case

The accelerated exploration schedule results in a mean gas production that increases steadily for 20 years. This is in contrast to the base case schedule shown in Figure 7-6 where mean production is forecast to drop after FY 2015 as existing fields go on decline. In the accelerated scenario new discoveries offset this decline in production from existing fields.

7.5 HIGH DEMAND GROWTH CASE

The supply model was run again with the high demand growth scenario described in Section 3.5. Figure 7-12 shows the results of this scenario. With the high demand growth scenario, it is highly unlikely that gas supply will meet demand at all through 2030. Significant domestic supply shortages (between 1 to 9 BCFD) are predicted to occur starting in FY 2016. Other sources of natural gas such as LNG or gas imports by pipeline would be necessary to support such high growth rate in gas demand.

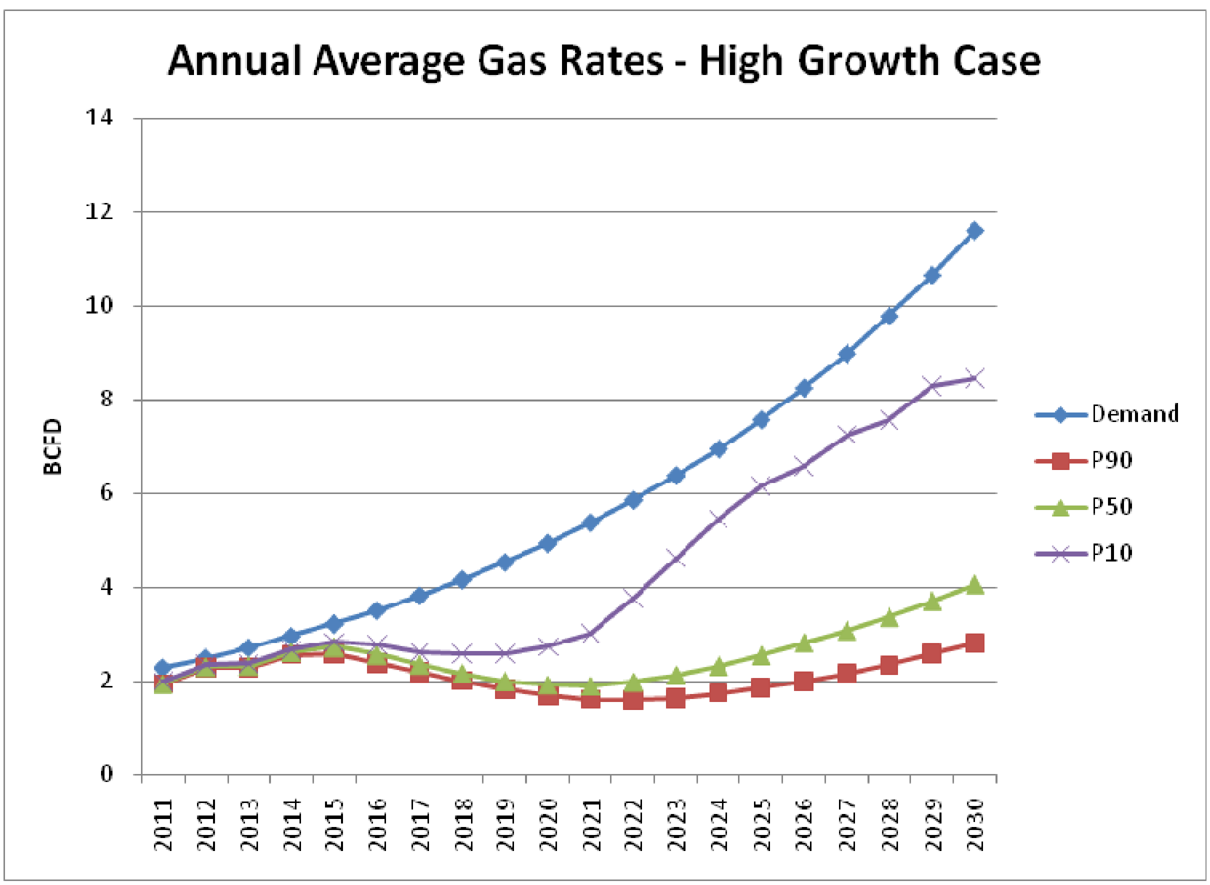

Figure 7-12 High Demand Growth - Annual average gas rates

7.6 ACCELERATED HIGH DEMAND GROWTH CASE

The high demand growth case was run a second time with the aggressive assumption of the accelerated timeline for prospects and leads. Figure 7-13 shows that there is at least a 10% chance that gas supply will be able to meet demand through 2030 even in the high growth case, although small shortages are forecast to occur in 2011, 2012, and 2013.

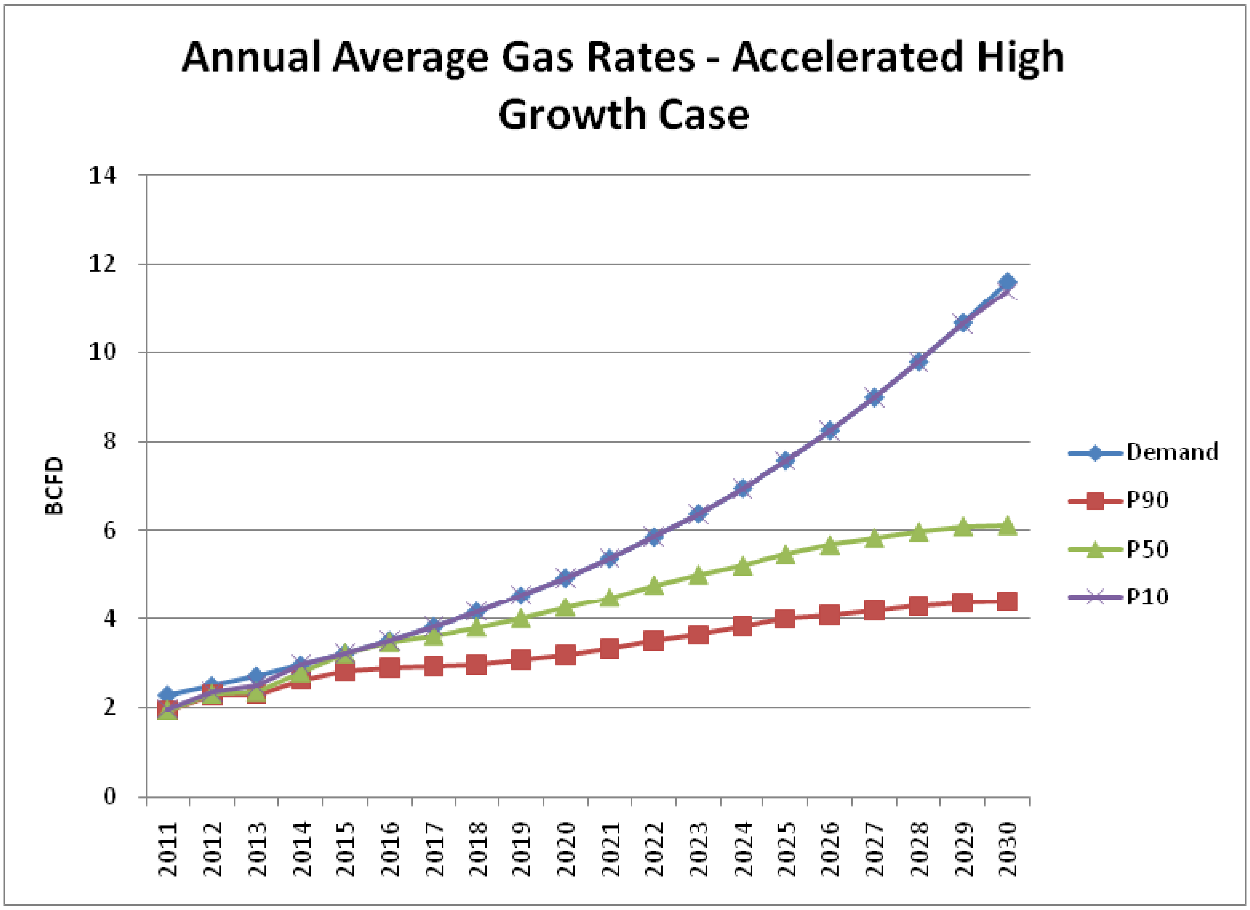

Figure 7-13 High Demand Growth with Accelerated Exploration

7.7 LOW DEMAND GROWTH CASE

The low demand growth scenario described in Section 3.5 was also considered. Figure 7-14 shows that small shortages may occur in the short term through 2015, but it is highly likely a gas shortage of greater than 1 BCFD will occur in the intermediate years (2016 through 2023). There is a greater than 10% chance that there will be a sufficient supply of gas in the late years.

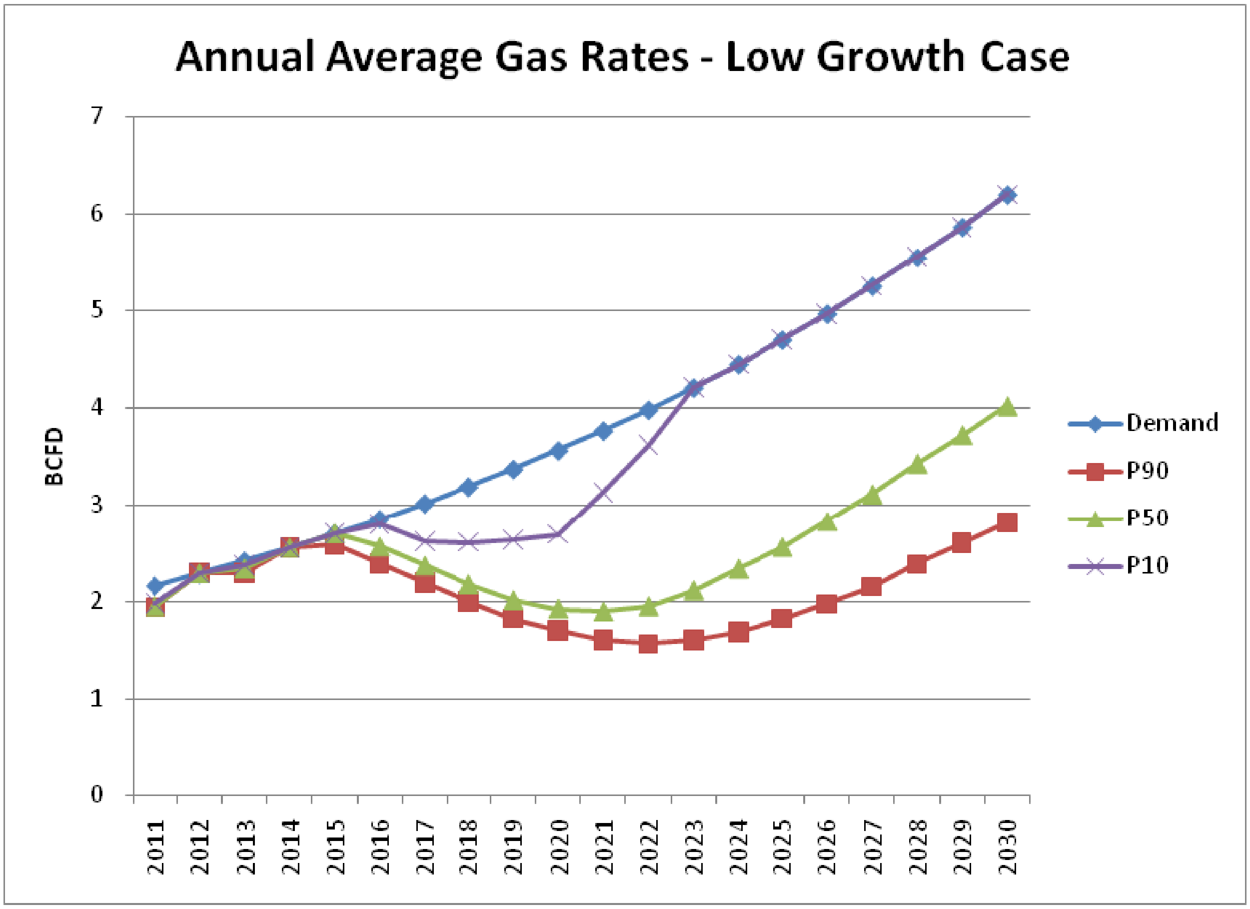

Figure 7-14 Low Demand Growth - Annual Average Gas Rates

7.8 ACCELERATED LOW DEMAND GROWTH CASE

The low demand growth scenario was also run with the accelerated timeline for prospects and leads. With this strong assumption, there is a greater than 50% chance there will be enough gas supplied to meet demand, except for small sporadic shortages in the early years, as illustrated in Figure 7-15.

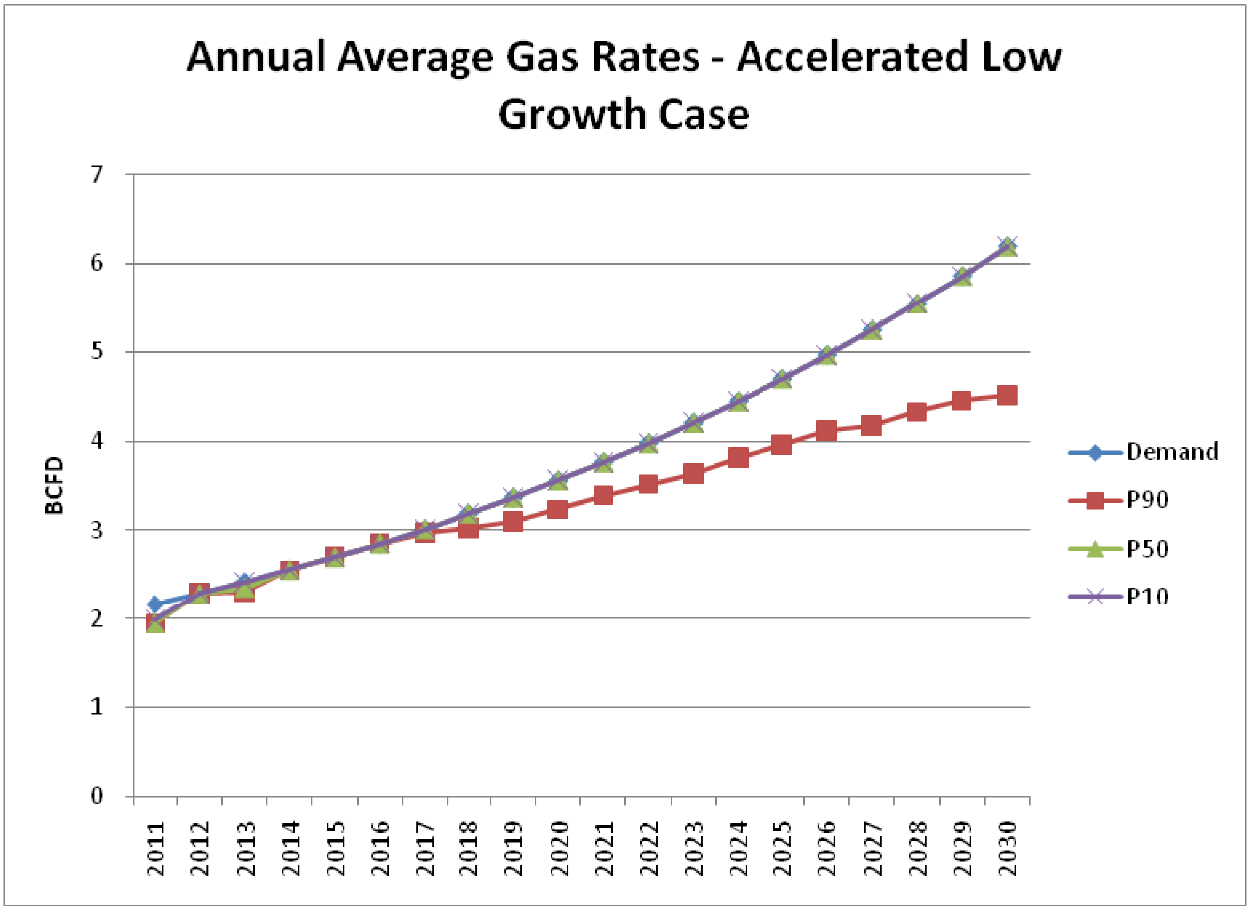

Figure 7-15 Low Demand Growth with Accelerated Exploration

8 CONCLUSIONS

Actual gas consumption in Bangladesh has grown by an average of 10.0% per year from fiscal year (FY) 1980[70] to FY 2009. The annual average gas consumption in FY2009 was 1936 MMCF per day. The annual consumption in that fiscal year was about 706 BCF. The previous gas demand forecasts that were reviewed tended to underestimate future gas demand. It is difficult to predict future gas demand accurately. This report considers 3 demand growth scenarios, each starting with actual gas consumption in FY 2009: a base gas case with demand growth of 7.3% per year, a low case with growth of 5.7% per year, and a high case with growth of 8.9% per year. The growth rate in each of these scenarios is lower than the long run historical average. This is reasonable, since the historical growth started with a very low rate of gas use in the country.

This report considered several actual and possible sources of gas:

- Existing fields
- New conventional fields
  - Mapped prospects and leads
  - Unmapped prospects and leads
  - Thin beds
- Unconventional sources
  - Coal bed methane (CBM)
  - Shale gas
- Gas imports
  - LNG
  - Pipelines

The country has been experiencing shortages of natural gas. Since much of the power generation in the country is gas-fired, the gas shortages have caused power load shedding during certain seasons. This has heightened awareness of the need to explore for and develop new sources of natural gas.

[70] Fiscal year 1980 runs from July 1, 1980 through June 30, 1981.

There is also awareness of the potential for reform of end-user tariffs for natural gas to moderate demand for natural gas. Residential consumers pay a low fixed monthly fee for natural gas regardless of actual gas consumption. Other categories of gas consumer pay a low price for gas. Tariff reform is being considered, which could lead to lower growth rates in gas demand.

Besides the range of future demand scenarios, the report presented a range of possible supply scenarios. Exploration and development of hydrocarbons is an intrinsically uncertain undertaking. There is uncertainty about whether a particular prospect, lead or target will contain commercial amounts of hydrocarbon, and if so, about the amount of hydrocarbon reserves or resources. There is also uncertainty about the timing of exploration activity and the rate of production from existing fields or new discoveries. We have built a probabilistic spreadsheet tool that models all of this uncertainty. The probabilistic inputs for the model are based on the Gustavson reserve and resource reports that were prepared earlier as part of this project.

The model predicts that there will continue to be small gas shortages over the next five years. Additional development is planned for existing fields, which will lead to increases in the supply of gas. However, the increases are not anticipated to keep pace with the increased demand for natural gas. We predict that domestic gas supplies will begin to fall substantially short of demand starting in about 2016, as production from existing fields goes on decline due to depletion of reserves within those fields. It is possible that large discoveries of shale gas may meet gas demand in late years after about 2024, but this is not assured.

The country has several options for dealing with the anticipated shortage in the domestic supply of natural gas, including:

- Accelerate natural gas exploration activity on the part of Petrobangla and/or international oil and gas companies
- Import natural gas as LNG, which will require construction of one or more LNG regasification facilities
- Initiate studies of unconventional gas (shale gas and coalbed methane) and thin beds in Bangladesh
- Arrange for import of natural gas by pipeline from neighboring countries

- Raise end-user prices for natural gas to moderate the demand
- Allow for more private sector involvement in the natural gas sector, for example allowing gas producers to sell gas to end users, with Petrobangla being compensated for providing transportation from the wellhead to the end user.

APPENDIX A

SECTOR DEMAND FORECASTS FROM PREVIOUS REPORTS

This appendix presents the values in the sector-wide gas demand forecasts of three of the four previous reports that Gustavson Associates has reviewed. The Global Data forecast did not include a gas demand forecast by sector; therefore it is not included in this appendix. The information in this appendix was gathered from the previous reports and summarized in table form below for quick comparison.

Table A-1 Econ Analysis Sector Demand Forecast[71]

Sector	Case	2000	2005	2010	2015	2020	2025	2030
Power	Base Case	408	563	756	1044	1409	1831	2452
	High Growth		563	923	1310	1882	2282	2736
	Low Growth		543	640	818	1033	1219	1499
Fertiliser	Base Case	233	247	304	306	282	282	230
	High Growth		265	342	345	321	321	269
	Low Growth		245	245	225	222	222	170
Industry	Base Case	125	213	314	410	509	615	717
	High Growth		276	408	541	682	836	989
	Low Growth		222	285	351	419	491	554
Other	Base Case	100	158	218	280	360	462	591
	High Growth		128	206	290	404	556	755
	Low Growth		100	130	167	222	292	382
Losses	Base Case	43	68	86	92	92	87	77
	High Growth		76	101	113	117	114	105
	Low Growth		58	65	67	66	62	54
Total	Base Case	908	1249	1676	2132	2652	3277	4067
	High Growth		1308	1980	2599	3406	4108	4854
	Low Growth		1167	1364	1628	1963	2286	2660

Units: MMCFD

[71] Source: ECON Analysis, *Bangladesh Optimal Gas Utilisation*, 2004.

Table A-2 Wood Mackenzie Sector Demand Forecast[72]

	Fiscal Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Power Sector	Base Case	600	652	709	771	838	911	990	1076	1169	1271	1382	1502	1633	1775	1929	2097	2279	2478	2693	2928	3182
	Low Growth	600	639	681	725	772	822	875	932	993	1058	1126	1199	1277	1360	1449	1543	1643	1750	1864	1985	2114
	High Growth	600	662	731	807	891	984	1086	1199	1324	1462	1614	1782	1967	2171	2397	2647	2922	3226	3561	3932	4340
Fertilizer	Base Case	274	274	274	274	274	280	280	280	280	280	280	280	280	280	280	280	280	280	280	280	280
	Low Growth	274	274	274	274	274	280	280	280	280	280	280	280	280	280	280	280	280	280	280	280	280
	High Growth	274	274	274	274	274	365	365	365	365	365	410	410	410	410	410	410	410	410	410	410	410
Non-Bulk	Base Case	500	539	580	625	673	725	780	840	905	975	1050	1131	1218	1312	1413	1521	1638	1765	1900	2047	2204
	Low Growth	500	532	565	601	638	679	721	767	815	867	921	979	1041	1106	1176	1250	1329	1413	1502	1596	1697
	High Growth	500	544	592	644	701	762	829	902	982	1068	1162	1264	1376	1497	1628	1772	1928	2097	2282	2483	2701
Total	Base Case	1362	1426	1525	1619	1725	1896	2022	2158	2340	2518	2669	2853	3030	3240	3509	3818	4112	4439	4792	5182	5606
	Low Growth	1362	1414	1503	1577	1672	1795	1896	2000	2096	2217	2299	2386	2476	2593	2754	2942	3125	3312	3528	3762	4005
	High Growth	1362	1440	1563	1666	1785	1983	2234	2426	2657	2873	3087	3379	3625	3942	4320	4739	5193	5698	6244	6830	7441

Units: MMCFD

[72] Source: Wood Mackenzie, Preparation and Development of Gas Sector Master Plan, 2006.

Table A-3 Petrobangla Sector Demand Forecast[73]

	Fiscal Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Power	Base Case	894	1010	1394	1525	1667	1681	1754	1768	1802	1822	1932	1956
Fertilizer	Base Case	232	232	240	240	240	240	240	296	296	296	296	296
Non-Bulk	Base Case	575	622	684	740	801	868	940	1018	1103	1196	1297	1408
Captive Power	Base Case	190	206	222	240	260	281	304	330	357	387	420	455
Total	Base Case	1890	2070	2540	2746	2969	3070	3238	3412	3559	3702	3945	4115

Units: MMCFD

[73] Source: Technoconsult International, "*Preparing the Gas Sector Development Program*, 2009

APPENDIX B

INPUTS FOR PROBABILISTIC MODELS

Average time between exploration wells, years	
Prospects	1.00
Leads	1.00
Unmapped	1.00
CBM	1.00
Shale gas	1.00

Exploration Start – Base Case

Date of 1st exploration well	Prospect	Lead
Awarded blocks (not yet in IOC hands)	8/1/2013	8/1/2015
Eastern fold belt, unawarded	8/1/2017	8/1/2020
Unawarded other	8/1/2019	8/1/2025
	Target	
Unmapped	8/1/2025	
CBM	8/1/2013	
Shale Gas	8/1/2016	

Exploration Start – Accelerated Case

Date of 1st exploration well	Prospect	Lead
Awarded blocks (not yet in IOC hands)	1/1/2012	1/1/2012
Eastern fold belt, unawarded	1/1/2012	1/1/2012
Unawarded other	1/1/2012	1/1/2012
	Target	
Unmapped	8/1/2025	
CBM	8/1/2013	
Shale Gas	8/1/2016	

Summary of Bangladesh Major Fields Gas Reserves						
Field	Estimated Ultimate Recovery (BCF)			Reserves		
	P90	P50	P10	P90	P50	P10
Shahbazpur	213.7	261.2	315.7	208.9	256.3	310.8
Chhatak	265.0	474.0	727.0	239.2	448.2	701.2
Bibiyana	4,075.2	4,531.7	4,988.3	3,226.5	3,683.0	4,139.6
Rashidpur	2,415.5	3,134.0	3,989.9	1,932.8	2,651.4	3,507.3
Kailash Tila	2,553.4	2,880.2	3,226.3	2,024.6	2,351.5	2,697.6
Bangora	557.7	621.4	686.3	397.7	461.4	526.4
Narshingdi	316.8	344.7	371.5	193.0	220.9	247.7
Salda Nadi	155.7	275.3	403.2	91.2	210.8	338.7
Fenchuganj	194.5	329.3	475.8	109.9	244.7	391.2
Moulavi Bazar	401.9	493.6	601.6	220.2	311.9	420.0
Titas	6,837.8	7,582.2	8,336.4	3,549.7	4,294.1	5,048.3
Meghna	76.4	101.2	208.6	38.5	63.3	170.7
Jalalabad	1,013.1	1,127.8	1,250.3	387.4	502.0	624.5
Bakhrabad	1,200.7	1,387.2	1,594.4	483.6	670.1	877.3
Sylhet	322.7	408.3	511.5	128.6	214.2	317.4
Beani Bazar	107.7	136.6	168.6	40.2	69.2	101.1
Sangu	677.3	770.5	863.7	196.4	289.5	382.7
Habiganj	2,412.8	2,786.8	3,220.8	607.7	981.7	1,415.7
Feni	62.8	129.6	202.0	0.0	66.5	138.9
Kamta	21.1	50.3	100.0	0.0	29.2	29.2
Begumganj	10.0	32.7	108.0	10.0	32.7	108.0
Kutubdia	45.5	45.5	100.0	45.5	45.5	45.5
Semutang	318.0	318.0	600.0	318.0	318.0	318.0

UNMAPPED	Ref. USGS Survey Bulletin 2208-A			
			Field Size BCF	
	Mean # fields	Rel. Freq.	Mean	SD
Surma Basin	33	21.0%	265	909
E. Extremely Folded Belt	7	4.5%	71	36
Hi-Amp. Faulted Anticlines	16	10.2%	114	171
Moderately Faulted Anticlines	74	47.1%	274	899
Western Slope	22	14.0%	140	409
Western Platform	5	3.2%	71	36
Total	157	100.0%		

POS 7.29%

Prospects on Unawarded Blocks NOT in the Eastern Foldbelt				
Name	**Block**	**Mean (BCF)**	**St Dev (BCF)**	Variance
10-2 (Char Jabbar)	10	438	127	16,025
12-3 (Balarampur/ Byronpur)	12	2,186	716	512,713
Kuakata	17	11,316	3,167	10,028,812
Adinath	17	3,790	1,423	2,025,811
Average		**4,433**	**1,774**	3,145,840

POS 9%

Prospects on Awarded Blocks NOT in the E. Foldbelt				
Name	**Block**	**Mean (BCF)**	**St Dev (BCF)**	Variance
Kapasia	11	2631	491	241,042
Netrakona	11	5081	1821	3,316,405
Char Kajal	7	3046	728	529,562
Average		**3586**	**1,167**	1,362,336

POS 9%

Prospects on Unawarded Blocks in the Eastern Foldbelt				
Name	Block	Mean (BCF)	St Dev (BCF)	Variance
Sundalpur	10	131	25	641
Chhatak East	12	1,331	255	64,867
Semutang East Strat	15	53	29	847
Semutang West Flank	15	68	24	592
Semutang South	15	91	32	1,028
Sandwip West	15	2,702	444	196,745
Sandwip South	15	539	115	13,239
Sangu East	16	181	53	2,794
Manpura	16	408	110	12,137
Maiskhali	16	962	193	37,369
Matabari Deep MS1	16	876	291	84,687
Matabari Shallow MS2	16	4,543	2,706	7,322,057
Sangu South	16	476	177	31,396
Hatia	16	1,787	561	314,699
Magnama	16	1,231	527	277,971
Kutubdia	16	2,272	715	511,597
Jaldi	16	1,005	313	97,675
Sonadia	16	263	103	10,623
Ukhia	17	2,082	485	235,215
D (Ohlataung)	17	1,379	329	107,939
E (Inani)	17	975	256	65,301
I (Dakhinila)	17	2,478	587	344,992
Teknaf	18	624	170	28,795
Coral Dip	18	2,547	619	383,384
St. Martin Island O	18	1,298	354	125,274
Average		**1,212**	**641**	410,875

POS 53.9%

Leads on Awarded Blocks (NOT in the Eastern Foldbelt)				
Name	**Block**	**Mean (BCF)**	**St Dev (BCF)**	Variance
Bajitpur	11	1,758	700	490,098
Madon	11	917	447	200,024
Nandail	11	3,263	1,218	1,482,891
Nikli	11	2,000	790	624,874
Bhairab (11-2,3)	11	1,585	684	467,706
Haluaghat (11-1/ Lead-C)	11	11	6	39
8-1 (L, M, E. Mio-Oligo)	8	1,831	542	293,255
8-2 (E. Mio. & Oligo)	8	754	230	52,780
8-3	8	823	256	65,388
8-4	8	401	138	19,146
8-5A (L, M, E. Mio-Oligo)	8	436	145	21,063
8-5B (L, M, E. Mio-Oligo)	8	612	199	39,681
8-5C (L, M, E. Mio-Oligo)	8	802	265	70,485
8-6 (L, M, E. Miocene)	8	368	123	15,203
8-7	8	1,499	555	308,025
8-8	8	3,424	1,205	1,451,664
8-9	8	736	352	123,693
8-10	8	312	188	35,168
8-11	8	678	363	131,660
8-12	8	1,214	472	222,463
8-13	8	2,825	990	980,496
8-14 (Eoc. & Cret)	8	444	233	54,256
8-15 (L. & M. Mio.)	8	250	87	7,646
Lead A	8	412	144	20,848
Lead B	8	266	133	17,796
Lead D	8	516	182	33,266
Lead E	8	481	168	28,056
Lead F	8	250	90	8,105
Lead G	8	1,131	359	129,226
Lead H	8	3,508	924	853,536
Chandramohan	7	952	275	75,394
Amtoli	7	595	188	35,213
Average		**1,095**	**511**	261,223

POS 8.1%

Leads on Unawarded Blocks NOT in the Eastern Foldbelt				
Name	Block	Mean (BCF)	St Dev (BCF)	Variance
2-1 (Oligo-Eo-Cre)	2	1,549	415	172,607
2-2	2	2,127	750	562,005
2-3	2	1,467	527	277,813
Sherpur East	2	579	169	28,507
3-1	3	3,537	1,239	1,534,972
3-2	3	5,280	1,634	2,668,584
3-3	3	2,232	812	659,052
3-4	3	660	248	61,578
3-5	3	2,472	698	487,316
3-6	3	3,169	876	767,078
3-7	3	3,047	1,015	1,029,677
3-8	3	1,464	516	266,524
3-9	3	1,467	523	273,791
3-10	3	264	123	15,063
3-11	3	530	175	30,674
3-12	3	331	176	30,825
3-13	3	265	123	15,191
3-14	3	265	124	15,391
4-1	4	4,459	1,481	2,191,880
4-2	4	3,565	1,177	1,384,623
4-3	4	5,610	1,870	3,496,376
4-4	4	127	58	3,364
4-5	4	263	120	14,309
4-6	4	347	163	26,517
4-7	4	409	203	41,225
4-8	4	335	157	24,580
4-9	4	79	42	1,767
4-11	4	260	121	14,731
4-12	4	266	125	15,623
4-13	4	429	170	28,859
4-15	4	83	45	1,982
4-16	4	351	165	27,166
4-18	4	352	166	27,450
4-10	4	399	184	33,867
4-14	4	356	167	27,806
4-17	4	267	125	15,563
4-19	4	395	181	32,606
4-20	4	1,918	590	348,206
4-21	4	1,470	518	268,210
4-22	4	1,471	521	271,608
4-23	4	1,471	519	269,714
6-3	6	2,714	674	454,478
6-4 (L. & M. Mio.)	6	1,114	280	78,187
6-5 (L. & M. Mio.)	6	3,514	813	660,953
6-7 (L. & M. Mio.)	6	3,355	830	688,253
12-10	12	2,251	396	156,571
Lead 19-A	19	9,661	4,335	18,794,219
Lead 19-B	19	3,864	1,825	3,332,049
Lead 20-A	20	11,071	4,857	23,590,643
Lead 20-B	20	7,297	3,501	12,253,780
Lead 20-C	20	12,996	5,667	32,113,189
Average		**2,220**	**1,466**	2,148,765

POS 8.1%

Leads on Unawarded Blocks in the Eastern Foldbelt				
Name	**Block**	**Mean (BCF)**	**St Dev (BCF)**	Variance
Srikail, North (?)	9	312	254	64,404
Chandpur (?)	9	256	205	41,833
9-2 (L. & M. Mio.)/ Daudkandi	9	868	226	51,062
Darbesh	13	912	220	48,519
Dupitila (?)	13	746	166	27,632
Fenchuganj-East ?	14	1,049	254	64,633
Patharia North Pitch	14	2,391	527	277,392
Patharia West	14	452	98	9,645
Harargaj	14	10,127	2,108	4,442,610
Harargaj North	14	2,420	524	274,911
Batchia North Pitch	14	6,645	1,457	2,121,975
J	17	1,282	330	108,715
Q	17	1,306	493	243,315
R	17	1,306	495	245,431
Bandarban	22	7,186	1,184	1,401,761
Barkal	22	2,695	501	250,911
Belachari	22	3,915	645	416,102
Bhuachari	22	1,019	234	54,583
Changohtang	22	1,769	322	103,813
Gilachari	22	1,599	283	80,049
Gobamura	22	3,211	577	333,402
Kasalang	22	3,213	588	345,274
Matamuhuri	22	11,746	2,078	4,316,006
Shishak	22	1,208	230	52,808
Uttan Chhatra	22	5,786	1,040	1,080,997
Average		**2,937**	**811**	658,311

POS 38.5%