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An Exploratory Review of Bangladesh Gas Sector: Latest Evidence and Areas of Further Research

Paper 17

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The present paper titled ***An Exploratory Review of Bangladesh Gas Sector: Latest Evidence and Areas of Further Research*** has been prepared jointly by Professor A. K. M. A Quader, Chemical Engineering Department, BUET, Dhaka and Professor Edmond Gomes, Petroleum and Mineral Resources Engineering Department, BUET, Dhaka. The paper was presented at a dialogue on the theme of ***Energy Sector of Bangladesh: What are the Knowledge Gaps?*** organised by the Centre held at CIRDAP Auditorium, Dhaka on January 24, 2002.

Assistant Editor*: Anisatul Fatema Yousuf,* Head (Dialogue & Communication), CPD
Series Editor: *Dr. Debapriya Bhattacharya,* Executive Director, CPD

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An Exploratory Review of Bangladesh Gas Sector: Latest Evidence and Areas of Further Research

I. INTRODUCTION

Natural gas today is recognised as an important indigenous hydrocarbon resource in Bangladesh. Its use as a fuel in Chhatak Cement Factory in 1960 from the Chhatak Gas Field marked its first commercial exploitation. It was fed to the first ammonia-urea grass-roots complex, NGFF at Fenchugonj in 1961. Since then over the years the consumption of natural gas has been increasing and it has contributed to the national development significantly.

Natural gas is now the major fuel for power generation in Bangladesh. It is the feedstock and fuel for production of urea fertilizer and ammonia. It is the fuel for many industries and commercial establishments. It is an important fuel for cooking in metropolitan areas like Dhaka, Chittagong, Sylhet, Comilla, Mymensingh, Tangail etc. replacing the usual fuel such as wood and kerosene.

Natural gas was first discovered in 1955 at Haripur (Sylhet Gas Field) and this was followed by the Chhatak Gas Field in 1959. Since then exploration of oil and gas resources has led to the discovery of 22 gas fields and 1 oil field. When Natural Gas Fertiliser Factory (NGFF) went on-stream the reserve and production ratio (R/P ratio) was about 40.

Petrobangla, the state owned corporation is today responsible for exploration and development of oil, gas and mineral resources of the country. Petrobangla and its subsidiary companies are carrying out their designated responsibilities including distribution and marketing of gas. Bangladesh Petroleum Corporation (BPC), another state owned corporation looks after the import, production and marketing of petroleum products including gas condensate produced by the gas fields. Some private companies are now involved in the bottling and marketing of LPGs of imported origin.

International oil companies (IOCs) right from the beginning have been involved in the exploration and development of oil and gas in this region under a wide range of contracting arrangement. After the emergence of Bangladesh, IOCs that were and are associated with exploration and development of oil and gas include: ARCO, INA-Naftaplin, Nippon Oil, Ashland, Canadian Superior Oil, Union Oil, Shell, Schimittar, Occidental, Cairn, Rexwood, UMIC and UNOCAL. Shell and UNOCAL are now producing gas from two fields under separate Production Sharing Contracts (PSCs) and Gas Purchase and Sale Agreements (GPSAs). On September 18, 2001 the production was 1042 MMSCFD and the two IOCs' contribution was 176 MMSCFD.

Since the beginning of operation by IOCs in the past decade, the current utilisation of gas in Bangladesh and its utilisation in future have come under close scrutiny. This has happened because of IOCs' desire to recover their investment as early as possible and to keep exploration vibrant. There are many options and there are implications attached to each one of them including suspicion and fear of being involved in oil politics of unknown consequences.

II. GAS EXPLORATION IN BANGLADESH (5, 23, 30-35,)

The exploration for oil and gas in the areas what constitute now Bangladesh was initiated by finding oil in 1908 and the first exploratory well was drilled at Sitakundu. This was followed by three more exploratory wells by 1914. The exploration activities since 1908 can be broadly divided into five distinct phases as listed in Table 2.1.

TABLE 2.1: EXPLORATION ACTIVITIES IN BANGLADESH SINCE 1910

Phase	Period	Number of Exploratory wells	Discovery
I	1908-33 British India	6	None Minor Oil Flow
II	1951-71 Pakistan	22	8 Gas Fields
III	1972-78	9	2 Gas Fields (One Offshore)
IV	1979-92	16	7 Gas Fields 1 Oil Field
V	1993-2000	13	5 Gas Fields (One Offshore)

After the emergence of Bangladesh the exploration by IOCs under production sharing contract was initiated. The country was divided into 23 blocks for PSC. Six IOCs were awarded 7 blocks under PSC in the early seventies. During the period of 1974-77, seven offshore exploratory wells were drilled with only one gas field discovery.

In 1988, under a new PSC, 4 blocks were awarded to two IOCs who drilled 4 exploratory wells leading to the discovery of one gas field. In the early nineties, the model PSC of 1988 was revised and 8 blocks have been awarded to four IOCs. Two of these IOCs have so far drilled 14 exploratory wells since 1994 resulting in the discovery of 3 gas fields including one offshore field; and there was one gas well blowout.

During the period 1972-2000, Petrobangla drilled 16 exploratory wells and discovered 9 gas fields and one oil field. Table 2.2 lists the exploration activities since 1972.

TABLE 2.2: EXPLORATION ACTIVITIES IN BANGLADESH SINCE 1972

Period	No. of Exploratory Wells Drilled	Discovery	Remarks
PETROBANGLA			
1972-1990	13	7 Gas Fields 1 Oil Field	
1991-2000	3	2 Gas Fields	
INTERNATIONAL	OIL COMPANIES		
1974-1978	7	1 Gas Field	PSCs Cancelled
1988-1991	4	1 Gas Field	PSCs Cancelled
1994-2000	14	3 Gas Fields	

In terms of gas reserves, IOCs under a wide range of PSCs have made major gas discoveries in Bangladesh. These IOCs including those operating during pre-1972 era have discovered total recoverable gas reserves of 14.19 TCF from 12 fields while Petrobangla has discovered a total recoverable gas reserve of 1.47 TCF from 10

fields. Since the emergence of Bangladesh, the IOCs' exploration has contributed 4.46 TCF to recoverable gas reserves and Petrobangla's discoveries have contributed 1.24 TCF to recoverable gas reserves.

The six plan periods consisting of five 5-year plans and one 2-year plan since 1974 envisaged over 40 exploratory wells to be drilled in the public sector; but in reality only 16 exploratory wells were drilled. Non-availability of funds was the main constraint in some plan periods.

During 1990s the exploratory drilling programme did not gather the desired momentum in spite of the presence of IOCs. Only 13 exploratory wells were drilled which means about 1.3 wells per year. Since 1997 BAPEX, the exploration company of Petrobangla has not undertaken any exploratory drilling. Of late IOCs have also slowed down their exploration drilling programmes.

III. PRODUCTION OF NATURAL GAS (17, 20)

There are now 53 production wells capable of producing more than 1300 MMSCFD of gas from 12 gas fields. The following five companies are producing gas:

Bangladesh Gas Fields Company Ltd. (BGFCL)
Sylhet Gas Fields Ltd. (SGFL)
Bangladesh Petroleum Exploration and Production Company (BAPEX)
Shell Bangladesh Exploration and Development B.V. (SHELL)
UNOCAL Bangladesh Ltd. (UNOCAL)

BGFCL, SGFL and BAPEX are subsidiary companies of Petrobangla. Shell and UNOCAL are IOCs operating under separate Production Sharing Contracts (PSCs).

BGFCL owns eight gas fields, namely- Titas, Habigonj, Bakhrabad, Narsingdi, Meghna, Begumgonj, Feni and Kamta. The production from the Kamta and Feni is now suspended. The production from the Bakhrabad field is likely to be suspended in near future. The Begumgonj field has not yet been developed.
Sylhet Gas Field Limited (SGFL) owns five gas fields, namely- Sylhet, Kailashtila, Rashidpur, Beanibazar and Chhatak; and one oil field, namely- Haripur. The production from the Chhatak gas field and the Haripur oil field is now suspended.

BAPEX has been given the responsibility of operating of the Saldanadi, Fenchugonj and Shahbazpur gas fields. It produces from the Saldanadi field. Shahbazpur and Fenchugonj fields are yet to be developed.

Shell Bangladesh Exploration and Development B.V. produces from one field, namely- Sangu and this is an offshore field. It also owns two other fields, namely- Semutang and Kutubdia. Kutubdia is an offshore field discovered in the seventies.

UNOCAL owns three gas fields, namely- Jalalabad, Maulavibazar and Bibiyana. It produces gas from the Jalalabad field.

IV. GAS RESERVES ESTIMATES BY DIFFERENT STUDIES (7, 10-12,18, 25, 37-40)

Reserve estimation is very important for the proper planning of the energy sector of the country. However, it must be recognised that the reserve estimation is a dynamic process and the reserve of a field/country needs to be updated with the exploration,

production and development activities. When it comes to reserve, one needs to have clear understanding of some technical terms to avoid confusion. While talking about the reserve, people often get confused by the interchanging use of the terms reserve and the *gas initially in place* (GIIP). GIIP is the total amount of gas found initially in a reservoir when the reservoir is discovered. However, GIIP needs to be updated with additional information as a result of production and development activities. Reserve is that portion of the GIIP that can be produced from the reservoir under the present technical and economic conditions. Another term that is quite frequently used now a days is *reserve growth*. Reserve growth is the additional reserve over that of the previous estimate of the discovered fields as a result of additional appraisal cum development activities and/or application of new technology. Finally, resource potential of a country means probability of finding new reserve in addition to that already discovered. Resource potential is a probabilistic estimate, and information like geological data, exploration history of the region, exploration history of similar but mature basins of other region, etc., is used in this kind of study. In this section various studies on reserve and resource potential of the country have been summarised.

***IKM Study* (10)**

In 1992, Intercom Kanata Management Ltd (IKM), a Canadian petroleum consulting company, conducted a comprehensive geological and reservoir engineering study on eight gas fields of Bangladesh. In this study, IKM conducted geophysical/petrophysical evaluation of the gas fields and updated the subsurface maps of the fields. On reservoir engineering side they conducted well testing and fluid properties evaluation of the gas fields and estimated the gas initially in place (GIIP) and the reserve. The results of IKM study are summarised in Table 4.1. It shows that the GIIP and the recoverable reserve of the eight fields are 15.651 TCF and 9.04 TCF, respectively.

TABLE 4.1: SUMMARY OF GAS IN PLACE AND RESERVE ESTIMATION BY IKM (1992)

Field	GIIP, BCF (Proven + probable)	Initial recoverable reserve, BCF (Proven + probable)	Remaining recoverable reserve[a], BCF
Bakhrabad	1,432	867	614
Beanibazar	243	167	167
Belabo	111	79	79
Habiganj	3,669	1,895	1580
Kailashtila	3,657	2,529	2478
Marichakandi	159	83	83
Rashidpur	2,242	1,320	1320
Titas	4,138	2,100	1243
Total	15,651	9,040	7,564

a. Based on cumulative production upto December 31, 1991.

***Petrobangla Study* (18)**

Petrobangla engages consultants from time to time to perform specific jobs and to undertake studies on their behalf for the development of different gas fields. On the exploration and production side, Petrobangla usually engages consultants to conduct and interpret seismic surveys, perform drilling, completion, work over, pressure survey, reserve estimation, etc.

Some of these consulting firms carried out studies to estimate and update the gas in place and reserves on behalf of Petrobangla. Welldrill (UK) Ltd. (39-40),

Hydrocarbon Habitat Study (7), IKM Study (10), and BCIF study conducted some of the important ones. Based on the findings of these studies, Reservoir Study Cell of Petrobangla has estimated/updated the gas initially in place (GIIP) and reserve of different gas fields. Summaries of gas initially in place (GIIP)and reserve estimates of different gas fields by Petrobangla are shown in Table 4.2. It shows that the total GIIP and initial recoverable reserve of Bangladesh are 24.745 TCF and 15.51 TCF, respectively. Out of this reserve, 4.07 TCF has been produced already (up to February 2001), and the remaining reserve is 11.42 TCF.

TABLE 4.2: GAS IN PLACE AND RESERVE OF DIFFERENT GAS FIELDS AS DECLARED BY PETROBANGLA

Sl. No	Fields	Year of Discovery	Reserve Estimated by		GIIP (proven + probable)	Recoverable (proven + probable)	Cumulative Production (Dec. 2000)	Net Recoverable
			Company	Year				
A. Producing								
1.	Bakhrabad	1969	IKM	1992	1432	867	586.568	280.432
2.	Habiganj	1963	IKM	1992	3669	1895	818.315	1076.685
3	Kailashtilia	1962	KM	1992	3657	2529	231.820	2297.180
4	Rashidpur	1960	IKM	1992	2242	1309	194.920	1114.080
5.	Sylhet	1955	HHS	1986	444	266	166.084	99.916
6	Titas	1962	IKM	1992	4138	2100	1783.400	316.600
7.	Narsingdi	1990	IKM	1992	194	126	29.205	96.795
8	Meghna	1990	IKM	1992	159	104	23.278	80.722
9	Sangu	1996	Cairn/Shell	1997	1031	848	91.026	756.974
10	Saidanadi	1996	Bapex	1996	200	140	14.816	125.184
11.	Jalalabad	1989	Unocal/PB	2000	1195	815	52.298	762.702
12	Beanibazar	1981	IKM	1992	243	167	4.681	162.319
	Sub-total A				**18604**	**11166**	**3996.411**	**7169.589**
B. Non-Producing								
13.	Begumganj	1977	Welldrill	1991	25	15	0	15
14	Fenchuganj	1988	Bapex	1988	350	210	0	210
15	Kutubdia	1977	Welldrill	1991	780	468	0	468
16	Shahbazpur	1995	Bapex	1995	514	333	0	333
17	Semutang	1969	HHS	1991	164	98	0	98
18	Bibiyana	1998	Unocal	2000	3150	2401	0	2401
19	Moulavibgazar	1999	Unocal	2000	500	400	0	400
	Sub-total B				**5483**	**3925**	**0**	**3925**
	Sub-total (A+B)				**240087**	**15091**	**3996.4**	**11094.59**
C. Production Suspended								
20	Chattak	1959	Niko/Bapex	1998	447	268	27	241.5
21	Kamta	1981	Niko/Bapex	1998	33	23	21.1	1.9
22	Feni	1981	Niko/Bapex	1998	178	125	40	85.49
	Subtotal C				**658**	**416**	**87.11**	**328.89**
Grand Total (A +B+ C) in BCF					**24745**	**15507**	**4083.52**	**11423.48**
Grand Total (A +B+ C) in TCF					**24.745**	**15.507**	**4.08**	**11.42**

Source: Marketing and Production Division, Petrobangla (Revived on 15/02/2001)

BUET Study (12)

Petroleum and Mineral Resources Engineering Department (PMRE) of Bangladesh University of Engineering and Technology (BUET) has recently conducted a *gas in place estimation study*. In this study gas in place values of all the fields under Petrobangla have been estimated using flowing material balance and volumetric estimation methods. Since sufficient pressure survey data are not available for most of the fields operated by Petrobangla, flowing well material balance method in which

flowing well pressure data instead of the static reservoir pressure data have been used in this study. The results have been compared with those of Petrobangla. The comparison shows that for a number of reservoirs estimation of this study is significantly higher than those of Petrobangla study. This happened because in this study some new information revealed by some recently drilled development wells have been used. Data from these recent development wells such as Titas field have shown that some of the reservoirs are much larger than expected. If all the gas fields are systematically developed, it is highly likely that the natural gas reserve of the country would increase from the present value. Summary of BUET Study provided in Table 4.3 shows that the GIIP of the material balance and volumetric study are 28.49 TCF and 24.401 TCF, respectively. The difference may be due to under estimation of the reservoir bulk volume or presence of water drive.

TABLE 4.3: ESTIMATED GIIP OF DIFFERENT GAS FIELDS BY BUET STUDY (2001)

Field	No. of sand	No of well	Estimated GIIP[a] (TCF)		GIP Petrobangla ,1998 (TCF)
			MB	Vol.	
Producing					
Titas	13	14	10.24	9.050	4.132
Habiganj	12	7	8.022[b]	3.669	3.669
Bakhrabad	5	8	1.120	1.332	1.432
Narsingdi	2	1	0.402	0.194	0.194
Meghna	1	1	0.095	0.160	0.159
Saldanadi	2	2	0.227	0.351	0.200
Sylhet	2	2	0.84	0.444	0.444
Rashidpur	2	7	3.189	2.243	2.242
Kailastila	3	4	3.588	3.656	3.657
Beanibazar	2	2	0.108	0.243	0.243
Non Producing					
Shahbazpur	1	1		0.514	0.514
Fenchuganj	3	2		0.404	0.350
Production Suspended					
Chhatak	1	1	0.406	1.900	1.900
Kamta	1	1	0.137	0.109	0.325
Feni	2	2	0.117	0.132	0.132
Total (TCF)			28.49	24.401	19.593

[a] Proven GIIP only
[b] May be overestimated due to water drive

Study by Shell (25, 26)

In 1998, Shell Bangladesh Exploration and Development B.V. carried out a study on the gas reserve base in all regions of Bangladesh. In this study five categories of resource base have been considered. These are: cumulative production, mature reserves (discovered and developed), immature reserves (discovered but not developed), identified potential, and unidentified potential.

In this study the undiscovered resource base has been assessed with the concept of 'chance of success'. The chance of success is based on a combination of the historical success rate and geological evaluation of the individual prospect. In this study, each prospect/field has been assigned a probabilistic volume range based on uncertainties in the input parameters. The risked volume is an assessment of the expected success volume, which is likely to be obtained from the undiscovered potential of a basin.

This study by Shell estimated the total resource base of the country as 38 TCF. This includes the total reserves of the discovered fields and undiscovered resource potential based on geological evaluation and exploration history of the country. Later in a presentation and in the light of the USGS-Petrobangla study Shell estimated the total resource base between 43 to 64 TCF, in which existing reserve 18.0 TCF, field growth 5-6 TCF, and the undiscovered resource potential 20-40 TCF.

***UNOCAL Study* (37)**
Unocal Bangladesh Ltd. conducted a study on *Hydrocarbon Resource Base of Bangladesh*. This study has estimated the existing recoverable reserve, field growth potential and further resource potential of six blocks. In this study existing reserve has been taken as 16.1 TCF including Bibiyana but excepting Moulavibazar.

The second category of their reserve is the field growth which includes additional probable reserve as a result of new technology and enhanced recovery technique applied to the existing fields. The field growth components considered in the study

are: 1) 3-D Seismic surveys, 2) Petrophysical thin bed analysis, 3) Compression, and 4) Reservoir management. This study estimated a probable reserve addition of 12.8 TCF of field growth (1.6 TCF from reservoir management, 3.2 TCF from 3-D seismic, 4.8 TCF from thin bed and 3.2 TCF from compression) from existing fields.

The third category that the study considered is the potential of new field discovery. The study considered 30 selected prospects from 6 PSC blocks of the country and estimated a mean probability of finding new discoveries to be 13.2 TCF (5.3 TCF for P90 and 22.6 TCF for P10). In the light of the USGS-Petrobangla study Unocal concluded the total hydrocarbon resource base of the country as 61 TCF, in which discovered reserve 16.1 TCF, field growth potential 12.8 TCF and undiscovered resource potential 32.1 TCF.

***USGS- Petrobangla Joint Study on Natural Gas Resources of Bangladesh* (38)**
A joint team of the *United States Geological Survey (USGS)* and Petrobangla conducted a study on natural gas resource assessment of Bangladesh. This study, which was funded by the U.S. Agency for International Development (USAID), estimated the natural gas resource potential of the undiscovered gas fields of Bangladesh. The assessment team consisted of six geologists from the USGS's World Energy Resources Assessment Team and seven geologists, geophysicists, geochemists, and a petroleum engineer from Petrobangla. A regional assessment geologist presented the geological and geophysical data needed for the formal assessment. International oil companies, namely- Unocal Corporation, Shell Bangladesh, and Cairn Energy PLC, were invited to present geological background and assessment information. The objective of the study was to assess the technically recoverable undiscovered gas resource potential of Bangladesh that might be found in a 30-year period (2000-2030) through a properly conducted exploration programme.

The USGS periodically conducts assessments of hydrocarbon resources of the United States and of the world. As a part of the process, regional geologists present descriptions of the petroleum geology and known hydrocarbon resources of the region to be assessed to the Assessment Team. This information is used to identify and describe Total Petroleum Systems (TPS) within the assessed region. Total Petroleum Systems encompass the natural process that begins with the generation of

hydrocarbons from kerogen-rich source rocks, then followed by the migration of hydrocarbons from their source area, and ends with their entrapment within reservoir rocks beneath relatively impervious seals. The area (or country) in which that Total Petroleum System is active then divided into Assessment Units (AU). Assessment Units are areas of specific geological terrain for hydrocarbon development within a given Total Petroleum System. Available historical oil and gas production data from existing wells and fields and information on discovered prospects and leads are then allocated to each AU. The AU is characterised as type of hydrocarbon, in this case gas, the minimum field size to be assessed (in this case 42 BCF), and the number of discovered fields exceeding the minimum size, and the median size of discovered gas fields. Geologic elements may be risked only when no fields of the minimum field size have been discovered within an Assessment Units (AU). In such a hypothetical AU, geologic risk probabilities are determined for adequate petroleum charge, reservoirs, traps, and seals, and the timing of geologic events. These probabilities are multiplied together to determine the geological risk for an accumulation of one deposit equal to or greater than the minimum field size. Accessibility is also risked to account for the possibility of adequate locations to allow for exploration for a field equal to or greater than the minimum field size to be found within a 30-year time frame. Utilizing these data, along with the historical knowledge of world petroleum resources and geology of hydrocarbon accumulations worldwide, the Assessment Team conducts an iterative analysis of each AU until they reach a consensus on the ranges of the numbers and sizes of undiscovered fields (minimum, median, maximum) in that unit. These data are fed into a computer simulation programme that generates probabilistic forecasts on the undiscovered resources such as natural gas, oil and their co-products contained within the AU.

Previously, the USGS had conducted an assessment of the Ganges-Brahmaputra province, including parts of India and Myanmar and almost all of Bangladesh, as documented in the World Petroleum Assessment 2000 (U.S. Geological Survey World Energy Assessment Team, 2000). The current assessment reflects new information for the time period 1995 to 2000 and utilizes considerable proprietary data.

The study divided the country into six AUs based on their geological attributes. These are: Bang0101-Surma Basin Assessment Unit; Bang0102-Easternmost Extremely Folded Assessment Unit; Bang0103-High Amplitude Faulted Anticlines Assessment Unit; Bang0104- Moderately Folded Anticlines Assessment Unit; Bang0105-Western Slope Assessment Unit; and Bang0106-Western Platform Assessment Unit. The assessment units are shown in Figure 4.1. Table 4.4 shows summary results for the onshore region, offshore region, and the grand total for all of Bangladesh. Table 4.4 shows that Bangladesh has a natural gas resource potential of 8.43 TCF with 95% probability, 65.7 TCF with 5% probability, with a mean potential of 32.12 TCF. The onshore area is more promising and has a potential of finding natural gas of 5.99 TCF with a 95% probability and of 48.33 TCF with 5% probability with a mean potential of 23.34TCF. The offshore has a potential of 2.44 TCF with a 95% probability and 17.37 TCF with 5% probability with a mean potential of 8.05 TCF.

The resource number's calculations indicate the range of probable resources that may be discovered if Bangladesh were actively explored during a 30-year time frame. In places, where detailed geologic information is lacking in Bangladesh, the assessment

team used geological play types that occur in similar geological provinces elsewhere in the world. In addition to the fairly well understood structural anticlines, which have thus far constituted the main play in Bangladesh, the assessment team recognised the potential offered by stratigraphic traps, plays at depth within the high-pressure zone and other possible plays. The study also considered the possible technological advances in the fields of exploration and production that may occur within the next 30 year time frame.

Figure 4.1: Estimates Of Undiscovered Natural Gas Resources Of Bangladesh.

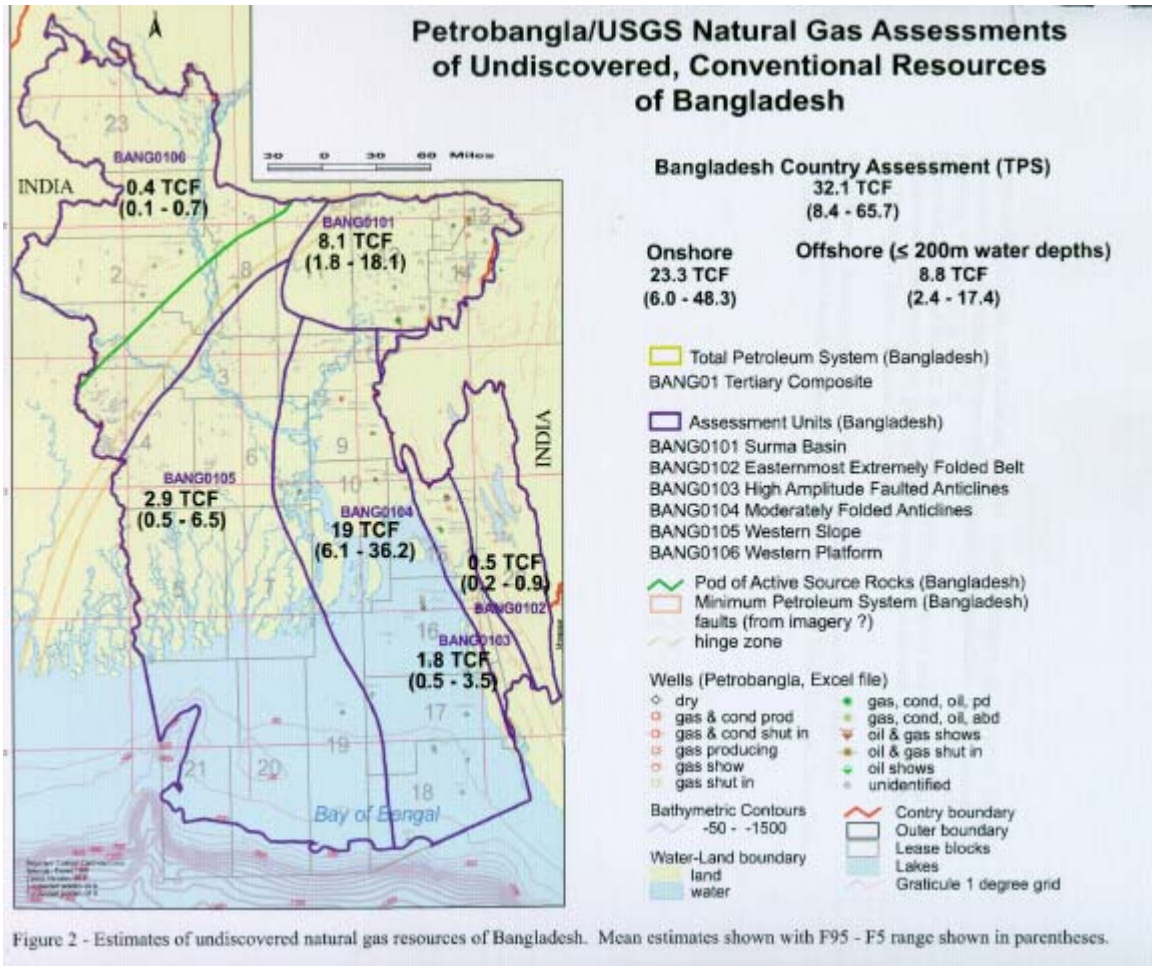


Figure 2 - Estimates of undiscovered natural gas resources of Bangladesh. Mean estimates shown with F95 - F5 range shown in parentheses.

TABLE 4.4: PREDICTION OF THE UNDISCOVERED GAS RESOURCES OF BANGLADESH BY USGS-PETROBANGLA STUDY

Area	Undiscovered gas resources, TCF			
	F95	F50	F5	Mean[a]
Onshore	5.99	21.11	48.33	23.34
Offshore	2.44	8.05	17.37	8.78
Total	8.43	29.17	65.7	32.12

a. From Monte Carlo Simulation

Hydrocarbon Unit and Norwegian Petroleum Directorate Joint Study (8)

A joint team of Hydrocarbon Unit (HCU) of Energy and Mineral Resources Division and Norwegian Petroleum Directorate (NPD) conducted the latest study to estimate the reserve of the discovered fields and undiscovered resource potential of the country. Experts of NPD on Norwegian side and those of Petrobangla, BAPEX, BGFCL, SGFL, and GSB conducted this joint study on HCU side.

This study re-estimated the reserve of four major gas fields, namely- Titas, Habiganj, Rashidpur and Kailashtilla, by material balance and volumetric methods utilising latest available data and reviewed the gas reserves of other discovered fields. For estimation of the resource potential, this study divided the country into two petroleum provinces comprising of six petroleum systems. This study identified the prospects, leads, plays, and selected reservoir parameters utilising latest information and available geological, exploration, reservoir and production data.

This study estimated the proven and probable gas initially in place (GIIP) of the discovered fields as 28.79 TCF and recoverable reserve as 20.44 TCF. Based on recent information, this study showed an increase in GIIP in Titas and Habiganj fields and a decrease in GIIP in Kailashtilla and Rashidpur fields. The study contended that using modern technologies and good reservoir management practices, it is possible to achieve a recovery factor of 70-75% in different gas fields compared to 52-70% used by Petrobangla.

The study estimated the undiscovered resource potential of the country between 18.5 TCF (90% probability) and 63.7 TCF (10%) with a mean of 41.6 TCF.

Remaining Recoverable Reserves of Gas

According to Petrobangla, the remaining recoverable reserves of 22 gas fields in June 2000 were estimated to be 11.596 TCF. The remaining recoverable reserves of 12 gas fields now producing 7.325 TCF and these reserves are listed below according to ownership.

Petrobangla:	5.652 TCF (Titas, Bakhrabad, Habigonj, Rashidpur, Kailashtilla, Sylhet, Beanibazar, Narsingdi, Meghna and Saldanadi)
Shell:	0.777 TCF (Sangu)
UNOCAL:	0.778 TCF (Jalalabad)

The remaining recoverable reserves of 10 non-producing fields are 4.271 TCF and these are listed below according to ownership.

Petrobangla:	1.904 TCF (Chhatak, Kamta, Feni, Shahbazpur, Begumgonj and Fenchugonj)
Shell:	0.566 (Kutubdia and Semutang)
UNOCAL:	2.801 TCF (Bibiyana and Moulavibazar)

Three non-producing fields Chhatak, Kamta and Feni under Petrobangla were taken out of production due to production of excessive water and sand. There is uncertainty with continual production from the Bakhrabad Field due to production of water and sand; and today four out of ten wells are producing gas at a reduced rate. Continued production from this field is uncertain.

Some recent development of wells as well as of studies show that the remaining recoverable reserves are higher than those officially recognised by Petrobangla. Unfortunately, most of the reserve figures of Petrobangla are based on studies conducted in 1991 or earlier. Petrobangla figures need to be updated based on recent development/appraisal activities and studies.

Table 4.5 summarises the GIIP, reserve, field growth, and resource potential of various studies conducted so far. It should be observed that scope as well as the results of various studies is quite different. Therefore, it will not be wise to compare the results of one study with those of others without mentioning the limitations. Also, there is a need to professionally evaluate the results of various studies.

TABLE 4.5: SUMMARY OF GIIP, RESERVE AND RESOURCE POTENTIAL OF DIFFERENT STUDIES

Name of the Study	GIIP (TCF)	Reserve (TCF)	Field Growth (TCF)	Resource Potential (TCF)
IKM[a]	15.65	**9.04**	-	-
Petrobangla	24.745	**15.51**	-	-
BUET[b]	24.4	**-**	-	-
Shell	-	**18**	5-6	20-40
Unocal	-	**16.1**	12.8[c]	13.2[d] (50%)
Petrobangla-USGS	-	**-**	-	32.1 (50%)
HCU-NPD	28.79[e]	**20.44**	2.03[f]	41.6 (50%)

a. Based on 8 gas fields
b. Based on producing gas fields of Petrobangla
c. Includes reservoir management, 3D, thin bed and compression
d. Based of 30 selected prospects of 6 PSC blocks
e. Re-estimated four fields, rest Petrobangla figures
f Includes compression only

V. USE OF NATURAL GAS

The use of natural gas in Bangladesh can be broadly divided into the following five categories:

- Power
- Fertilizer (urea, ammonia and ammonium sulphate)
- Industrial
- Commercial and
- Domestic.

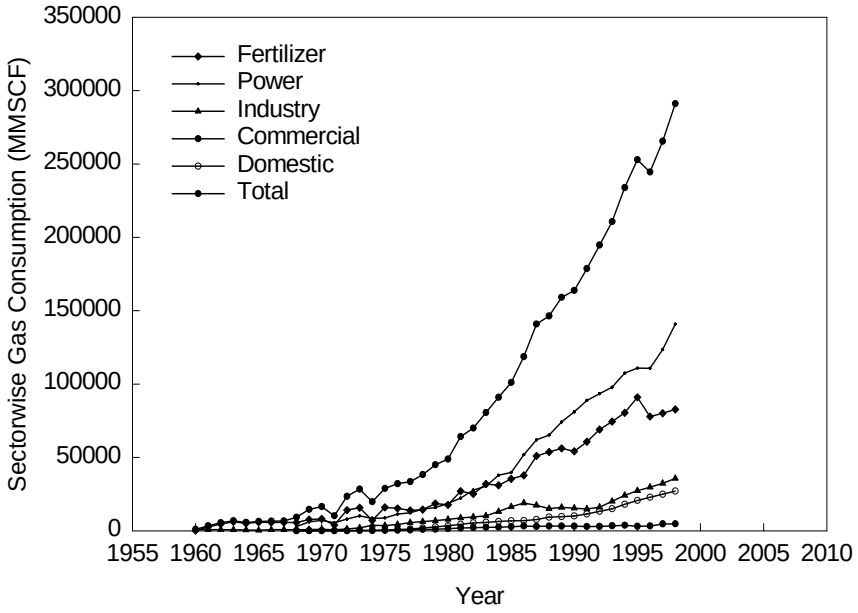
There are some seasonal users like the brickfields. The consumption pattern during the past decade shows that power sector consumes approximately 45%, fertilizer 35%, and the other sectors (industrial, commercial, domestic and seasonal) 20% of the gas (5,19).

VI. CONSUMPTION OF NATURAL GAS IN DIFFERENT SECTORS AND THEIR GROWTH (2- 5,9, 14, 24, 28)

As already stated in the introduction, the use of natural gas began in 1960; since then the consumption and its growth have been on the rise. There has been a step jump in gas consumption and its growth every time with the commissioning of a fertilizer

complex or a gas fuelled power plant. Figure 6.1 shows the sector wise cumulative consumption of natural gas since 1960.

FIGURE 6.1: SECTORWISE NATURAL GAS CONSUMPTION



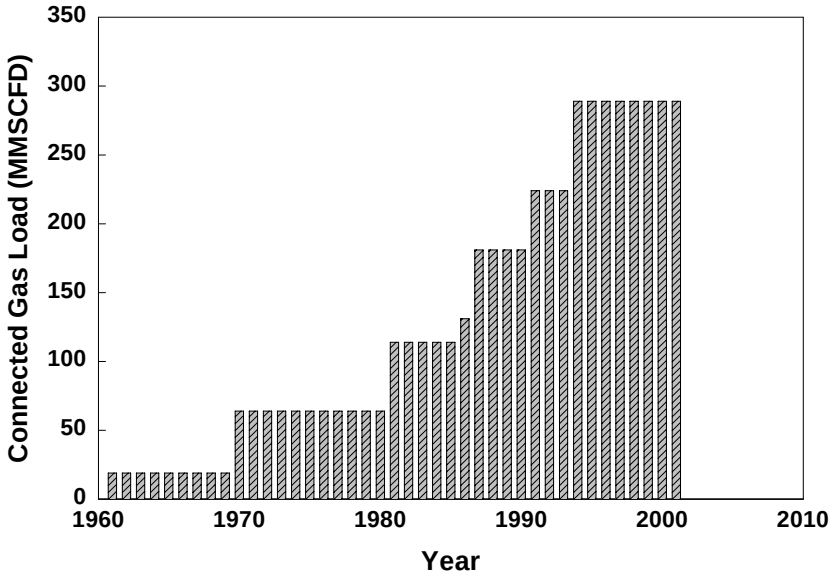
Urea Fertilizer Sector

Seven grass-roots urea complexes now in operation have a combined connected demand of 289 MMSCFD. Table 6.1 and Figure 6.2 show the growth of the sector. During 1988-1997 the share of this sector accounted for 32% to 37% of the total gas consumed.

TABLE 6.1: CONNECTED LOAD OF GAS FOR FERTILIZER SECTOR

Year	Plant	Load (MMSCFD)	Cumulative Load (MMSCFD)
1961	NGFF	19	19
1970	UFFL	45	64
1981	ZFCL	50	114
1986	PUFF	17	131
1987	CUFL	50	181
1991	JFCL	43	224
1994	KAFCO	65	289

FIGURE 6.2: GROWTH OF FERTILIZER SECTOR



A gas load of 67 MMSCFD was added by the fertilizer sector during 1986-1987 with the commissioning of PUFF and CUFL while an additional load of 108 MMSCFD was added during 1991-94 when Jamuna Fertilizer Company Limited (JFCL) and KAFCO came on-stream. The average daily demand of gas by the sector for the years 1986, 1989 and 1996 were 103, 154 and 213 MMSCFD respectively against the contracted loads of 121, 171 and 289 MMSCFD respectively. During the next five years up to 2005, the most optimistic annual consumption of gas would be 90 BCF per year by this sector.

The ammonia-urea complexes in Bangladesh were designed to operate 310-330 days a year. Actual on-stream days achieved have been below the design days for most of the plants for most of the years since their commercial operation started. Moreover, the connected gas load was established with a margin of 9-11% above the design gas consumption. Average consumption of gas today by these plants is about 85% of the connected load. Operation of the plants at design capacity will not, however, lead to extra consumption of gas annually as it will be more energy efficient at design capacity having less number of plant shutdowns.

Power Sector

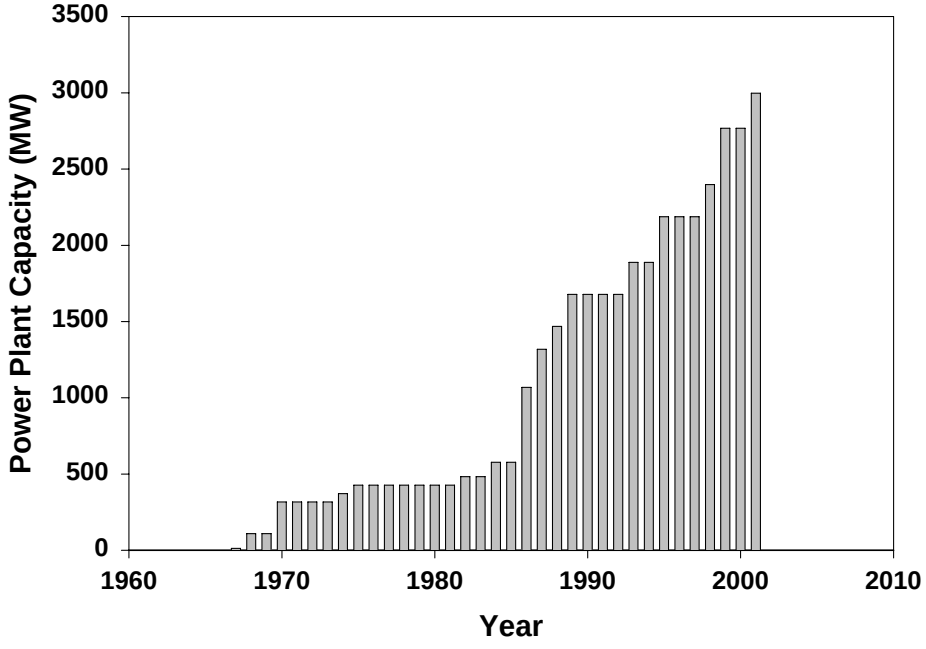
Today there are nine major installations, where electric power is generated using natural gas as fuel under PDB. Some independent power producers (IPP) are also engaged in electric power generation. The gas fuelled electricity generation capacity in June 2001 was 2970 MW with the largest installation at Ghorasal with the installed capacity of 950 MW. IPPs' gas based generation capacity is 390 MW. Table 6.2 and Figure 6.3 show the growth of natural gas based power plants since 1967.

TABLE 6.2: GROWTH OF NATURAL GAS FUELLED POWER PLANTS

Year	Power Plant Brought On-stream, MW	Cumulative Capacity Based on NG, MW
1967	13	13
1968	96	109
1970	208	317
1974	55	372
1976	55	427
1982	56	483
1984	94	577
1986	492	1069
1987	249	1318
1988	150	1468
1989	210	1678
1993	210	1888
1995	300	2188
1998	210	2398
1999- June 2000	370 including Mymensingh (70) and Baghabari (90)	2768

During 1986-90, 1101 MW generation capacity was added; 510 MW was added during 1991-95 and 790 MW has been added since 1996. The majority of the gas fired steam power plants have been procured from Russia and China; and these account for 1370 MW excluding the 210 MW unit under construction at Siddirgonj. IPPs generate electricity-using GTs.

FIGURE 6.3: GROWTH OF GAS FUELLED POWER PLANTS



The average demands of gas for power generation for 1985, 1986, 1989, 1996 and 1999 were 109, 142, 203, 303, and 375 MMSCFD respectively. The on-stream factor (annual plant factor) of the gas fuelled power plants ranges between 35% and 78%.

The typical daily load curve for electric power indicates that the duration of peak demand is about 5 hours beginning at about 6 pm and ending at around at 11 pm (3). The demand exceeds the average demand by about 50%.

The major consumers of electricity belong to the industrial and residential sectors. In 1994-95 the industrial and residential sectors used approximately 41% and 39% respectively of the total electricity consumed. The industry sector showed a growth of 5.2% during 1986-96 while the residential sector grew by 14%. The overall growth of consumption during the same decade was 7.7%.

The consumption of electricity in the agriculture sector during the past fifteen years ranged between 7.7% and 17% of the total consumption with no definite trend. Electricity demand for agriculture (mostly for operating pumps) is a managed load and does not clash with the peak load. The rainfall influences the demand during farming season. However, the consumption of electricity and diesel in agriculture for irrigation has been on the rise over the years.

Industry Sector

The industry sector during the current decade has been consuming 8% to 12% of the total gas consumption. Major application areas include: steam generation, captive power and process (heating media and heat source/fuel). When Bangladesh Gas Systems Limited (BGSL) had made its gas available in Chittagong area, industries using furnace oil, diesel or other liquid fuels immediately switched over to gas. These include: ERL, TSP, KPM, KRC, Osmania Glass, Chittagong Steel Mills, Dry Dock, etc. The sector has shown a growth of 3.75% during the decade. Table 6.3 lists the consumption of gas and its growth in this sector during 1991-2000 according to the three gas transmission and distribution companies.

TABLE 6.3: CONSUMPTION OF GAS BY INDUSTRY SECTOR DURING 1990-2000
(served by 3 Gas Companies)

Year	Gas Consumption Served by Companies, MMCM		
	TGTDCL	BGSL	JGTDCL
1990-91	204	132	
1991-92	222	128	
1992-93	264	133	
1993-94	353	146	
1994-95	447	158	
1995-96	528	159	57
1996-97	614	149	53
1997-98	729	145	45
1998-99	818	148	39
1999-2000			41

The consumption of gas in the franchise areas of BGSL and JGTDCL in past five years has been rather stagnant and does not show any noticeable growth. On the other hand, the consumption of gas in the franchise areas of TGTDCL during 1991-2000

has shown a steady growth. It is likely that most of the industries have been installing gas engine driven generators as captive power source instead of being dependent on PDB's unreliable supply. After a few years this growth will slow down.

The chemical process plants in Bangladesh normally generate their own electric power independent of the supply from PDB for reliability and economy. BCIC in its larger chemical process plants including fertilizer, pulp & paper, cement etc. has an installed generation capacity of 230MW including stand-by generators. However, the gas load for power generation is included in the connected load of the plant. A modern ammonia-urea complex having a capacity of 500,000-ton urea/year would require and generate about 8-10 MW electric power. The requirement of electric power for the manufacturing sub-sectors such as textile, jute and RMG is even less based on per unit total capital investment compared to process industries. These industries are likely to have generators based on dual fuels requiring gas supply. Many of these industries do not operate in three shifts a day. Whenever the stand-by or the captive generators are operated, the power from PDB is not used. It leads to a high peak gas demand while the actual gas consumption remains about the same.

Domestic Sector

The domestic consumers use gas as a fuel for cooking mainly. In recent years some affluent customers have been using gas for stand-by generators and raising hot water. This sector during the current decade has been using 8% to 10% of the total gas consumption. The number of domestic consumers now stands approximately at 900,000. The three transmissions and distribution companies can provide gas connection to about 70,000 new customers each year (TGTDCL: 50,000, BGSL: 15,000 and JGTDCL: 5,000). This sector has shown a growth of about 11.7% during 1986-95.

According to TGTDCL, in the year 1996-97, a domestic consumer consumed about 82 SCFD. Table 6.4 shows the growth of this sector during 1991-2000 in the franchise areas of the transmission and distribution companies.

TABLE 6.4: CONSUMPTION OF GAS BY DOMESTIC SECTOR DURING 1991-2000
(served by 3 Gas Companies)

Year	Gas Consumption Served by Companies, MMCM		
	TGTDCL	BGSL	JGTDCL
!990-91	241	36	
1991-92	255	52	
1992-93	296	60	
1993-94	333	73	
1994-95	399	93	
1995-96	441	107	43
1996-97	481	119	44
1997-98	530	136	48
1998-99	565	152	52
1999-2000			56

Commercial Sector and Seasonal Users

The commercial sector accounts for less than 1.5% of the total gas consumption and this has not shown significant growth during the current decade. The seasonal users,

mainly the brickfields, consume a small quantity of gas during the brick-manufacturing season. This is a minor sector for near future.

VII. PROJECTIONS OF GAS DEMAND IN BANGLADESH (1, 9, 11, 19, 27, 30-34, 36)

Since the emergence of Bangladesh, there have been several projections of natural gas demand. These are reported in the planning documents of various plans (five 5-year plans and one 2-year plan), ADB study, Task Force Report, National Energy Policy Report and Petrobangla's own report/study (1, 11, 13, 30-35,). These documents while making projections have envisaged considerable annual growth of the power and fertilizer sectors continuously. Some of the important underlying assumptions include:

- 7% to 10% increase in gas demand for fertilizer yearly
- 10-13% growth of natural gas fuelled power generation yearly
- industrial growth in excess of 7% requiring 7% rise in gas demand yearly
- growth of gas demand to exceed the growth in GDP

Even the popular articles and reports related to gas demand and future need, which have appeared recently in newspapers etc. speak of 10% annual growth of gas demand in Bangladesh.

Figures 7.1 and 7.2 show some of these projections of gas demand since 1973 by the five 5-year plans and different studies as average and peak respectively plus the actual consumption of gas. The First 5-year plan (1973-78) assumed that the power sector by 2000 would consume about 700 MMCFD gas supporting 5000 MW gas fired steam generating power plants at 60% plant factor, and the proven gas reserves of 8.29-9.36 TCF would be exhausted by then (30). In 1973, the generation capacity of gas based power plants was just 317 MW. It is clear that the projected daily demands of gas either as peak or average has always been above the actual consumption by a wide margin. For example, the projected peak daily demands of 1999 according to the Fifth 5-year plan, National Energy Policy (NEP) and Petrobangla are 1470, 1350 and 1112 MMSCFD, respectively, while the actual peak production in March 2000 was 1015 MMSCFD.

FIGURE 7.1: PROJECTION OF GAS DEMAND AND ACTUAL CONSUMPTION
(DAILY AVERAGE)

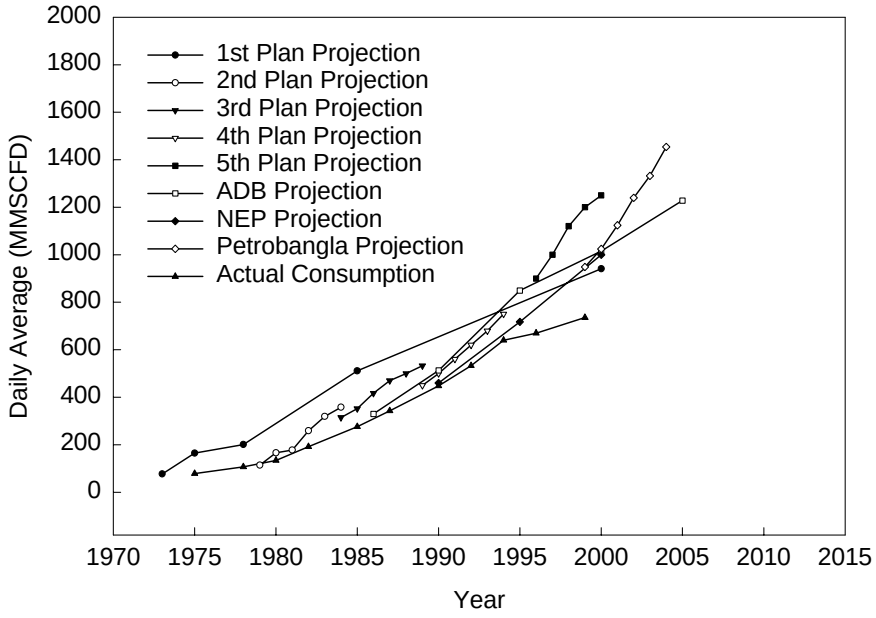
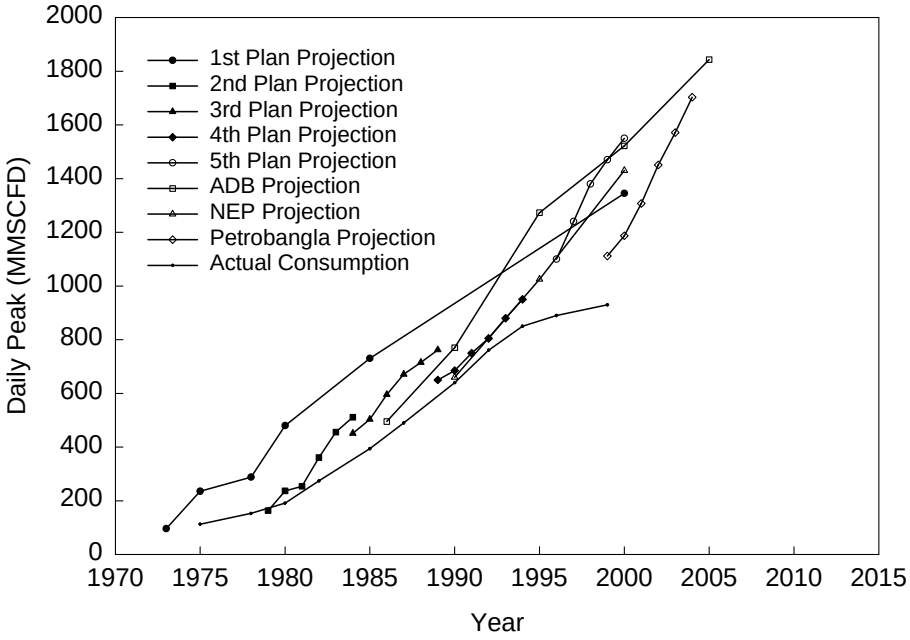


FIGURE 7.2: PROJECTION OF GAS DEMAND (DAILY PEAK)



The projected demands in the context of gas reserves have always predicted that the reserves would be exhausted by the end of a particular year (19, 27). For example, the latest projection supported by Petrobangla predicts that the gas reserves of 10.46 (excluding Bibiyana and Moulavibazar) would be exhausted by 2015 if the demand grows as projected. This projection assumes that power generation in 2005 will reach 5,264 MW and 11,035 MW in 2015. The same projection further assumes that the fertilizer sector will require additional 234

MMSCFD gas in 2005 for five new urea complexes of CUFL's size and expansion of Chittagong Urea Fertiliser Limited (CUFL). The projection seems to be highly optimistic.

VIII. GAS UTILISATION IN THE FUTURE (5, 11, 23)

As already mentioned the current utilisation pattern shows that the ammonia-urea fertilizer sector consumes approximately 35%, power 45% and other sectors (industry, domestic, commercial and seasonal) 20% of the gas consumption. We examine here the utilisation of gas in the future by these sectors one by one.

Fertilizer Sector

The growth of the ammonia-urea fertiliser sector in the future will be limited. A 500,000-ton/year capacity urea plant to be located at Fenchugonj to replace the existing 39-year-old NGFF is a possibility by 2005. It would mean an additional demand of about 25 MMSCFD gas if NGFF were shut down.

By 2005, another 500,000-ton per year urea complex is likely to be built on the western bank of the river Jamuna. This will create an additional demand of 40 MMSCFD gas. With these two plants on-stream the country in 2010 will have a total urea production capacity close to 4 million ton per year including KAFCO as against the current urea consumption of about 2.2 million ton per year.

If the two proposed 800 ton per day DAP plants to be built nearby CUFL come on-stream by 2005, these would further augment urea availability by about 200,000 ton/year. However, these two plants would create a demand for gas of 1.65 MMSCFD for steam and power generation.

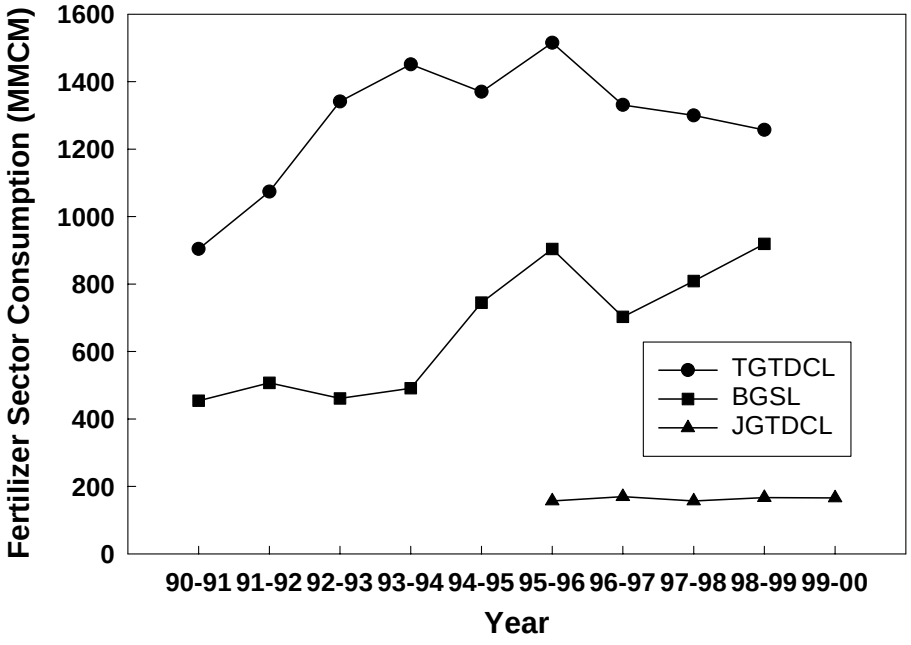
This means that during the period 2002-2005, the gas consumption by this sector will remain static to about 90 BCF per year as mentioned earlier. If the 500,000-ton per year ammonia-urea complex at Fenchugonj and two DAP plants come on-stream by 2005, the gas demand would be increased by about 27 MMSCFD.

From Tables 6.1 and 8.1 and Figures 6.1 and 8.3 it is evident that demand or consumption of gas by this sector does not increase without the commissioning of new plants. For example, since 1994 (after the commissioning of JFCL) the connected load for this sector has remained stagnant at 289 MMSCFD.

TABLE 8.1: CONSUMPTION OF GAS BY FERTILIZER SECTOR DURING 1991-2000
(served by 3 Gas Companies)

YEAR	Gas Consumption Served by Companies, MMCM		
	TGTDCL	BGSL	JGTDCL
1990-91	904	454	
1991-92	1074	507	
1992-93	1341	461	
1993-94	1451	491	
1994-95	1370	745	
1995-96	1515	904	157
1996-97	1331	703	170
1997-98	1300	809	157
1998-99	1257	919	167
1999-2000			166

FIGURE 8.3: GAS CONSUMPTION BY FERTILIZER SECTOR (1990 – 2000) AS SERVED BY THREE COMPANIES



Power Sector

The current development in the power sector suggests that PDB on its own will not build new power plants after the on-going plants, namely- 210 MW gas based Siddhirgonj plant and 300 MW coal based Barapukuria plant. It is likely that PDB will not build any more power plants beyond 2005.

PDB's role as a power plant builder is henceforth being replaced by IPPs. The much-talked Western Region Integrated Project (WRIP) has been shelved. IPPs' plants are troubled by many ifs and buts including funds and concessions. IPPs have planned to produce 1260 MW power by 2005 (Meghnaghat-1 and 2 of 450 MW each and Haripur 360 MW); and would require about 150 MMSCFD gas at the peak and 120 MMSCFD on the average.

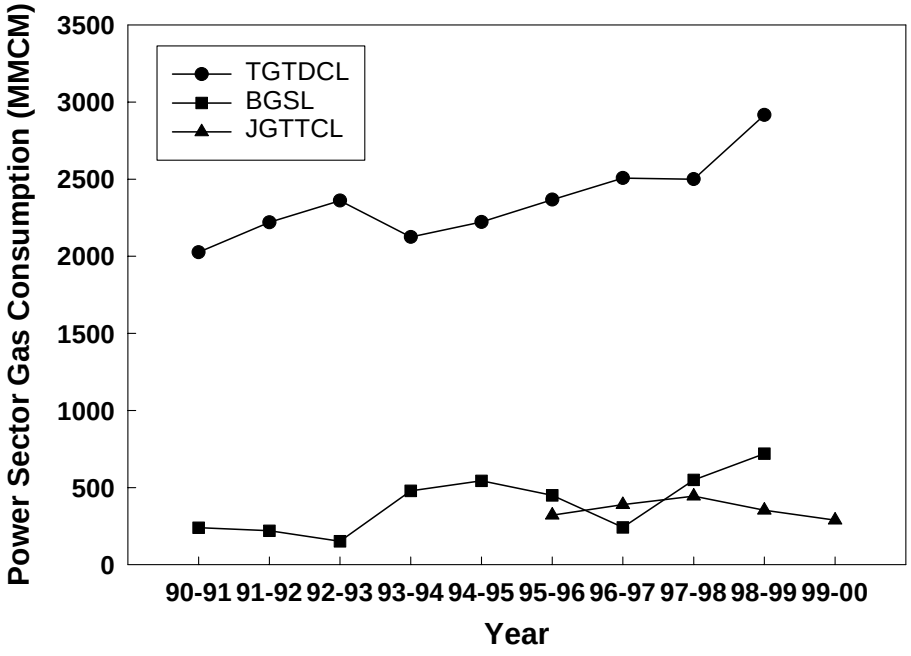
By 2005, if things proceed as planned; the gas based generation capacity would be increased by 1400 MW (PDB: 210 MW and IPPs: 1260 MW). 1700 MW would augment the total generation capacity if the Barapukuria plant comes on stream. This will certainly improve the availability of power. Moreover, the installation of the captive and stand-by gas engine generators by the industries will further improve the power supply and its reliability.

From Tables 6.2 and 8.2 and Figures 6.3 and 8.4 it is evident that the demand or consumption of gas in the power sector does not increase without the commissioning of new plants. During the plan period 1995-2000, the additional gas fuelled power generation capacity was 580 MW against the envisaged projection of about 1800 MW. In the 1990s the additional gas based generation capacity was 1090 MW in spite of the participation by IPPs and RPC.

TABLE 8.2: CONSUMPTION OF GAS BY POWER SECTOR DURING 1991-2000
(served by 3 Gas Companies)

Year	Gas Consumption Served by Companies, MMCM		
	TGTDCL	BGSL	JGTDCL
1990-91	2026	240	
1991-92	2220	220	
1992-93	2361	152	
1993-94	2125	479	
1994-95	2222	544	
1995-96	2367	450	321
1996-97	2507	242	390
1997-98	2500	550	445
1998-99	2916	720	353
1999-2000			289

FIGURE 8.4: GAS CONSUMPTION BY POWER SECTOR (1990 – 2000)
AS SERVED BY THREE COMPANIES

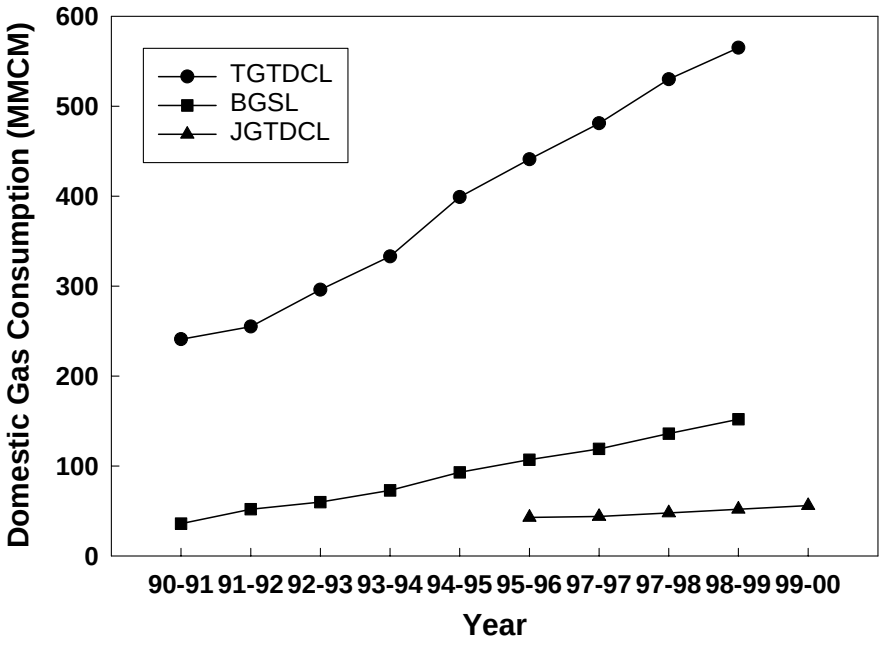


The industries, because of PDB's unreliable power supply and load shedding, have been installing their own captive gas engine generators. This would add additional gas based generation capacity of about 1000 MW requiring an additional gas demand of about 150 MMSCFD at the peak. This will not necessarily mean an increase of annual gas consumption by the same quantity, because the industries with captive power will not use PDB's supply. There will be surplus power available at the peak hours. Load management under these circumstances by both power and gas sectors will be a problem technically as well as financially. For the gas sector, there will be large differences among peak demand, average demand and connected load. Such large differences are undesirable from commercial point of view and resource wise this is certainly wasteful.

Domestic Sector (Cooking Fuel)

The consumption of gas in the domestic sector as a cooking fuel will continue to rise (Table 6.4 and Figure 8.1). However, the four transmission and distribution companies including the newly formed company the Pashchimanchal Gas Company Ltd. (WES GAS) would be able to provide gas connection to about 70,000-75,000 households per year provided the funds for the expansion of pipeline network are available. This additional connection means additional gas demand of about 6.4 MMSCFD based on daily consumption of 82 SCF per connection. This will give rise to an annual increase of gas consumption by this sector by 2.33 BCF. The trend is not going to change overnight just because the gas is available on the western bank of the river Jamuna. When the demand of the larger metropolitan areas like Dhaka and Chittagong will be fully served, the sector will find the growth diminishing. The current growth has little bearing on the growth of the economy or GDP. Because having a gas connection is an option for replacing the existing fuel type in use leading to convenience of cooking.

FIGURE 8.1: GAS CONSUMPTION BY DOMESTIC SECTOR (1990 – 2000) AS SERVED BY THREE COMPANIES



Industry Sector

The consumption of gas in the industry sector will continue to rise in the franchise areas of TGTDCL (Table 6.3 and Figure 8.2). The franchise areas under WES GAS will show some initial growth as shown by BGSL and JGTDCL (Table 6.3 and Figure 8.2).

Adding the system loss of 55 MMSCFD to this sector is a distortion. This has not led to additional sale revenue not to speak of proportional increase.

The consumption in the franchise areas served by BGSL and JGTDCL has remained static during the current decade 1991-2000. No growth is noticeable (Figure 8.2). Probably the potential industries were served as soon as the gas had become available.

FIGURE 8.2: GAS CONSUMPTION BY INDUSTRY (1990 – 2000)
AS SERVED BY THREE COMPANIES

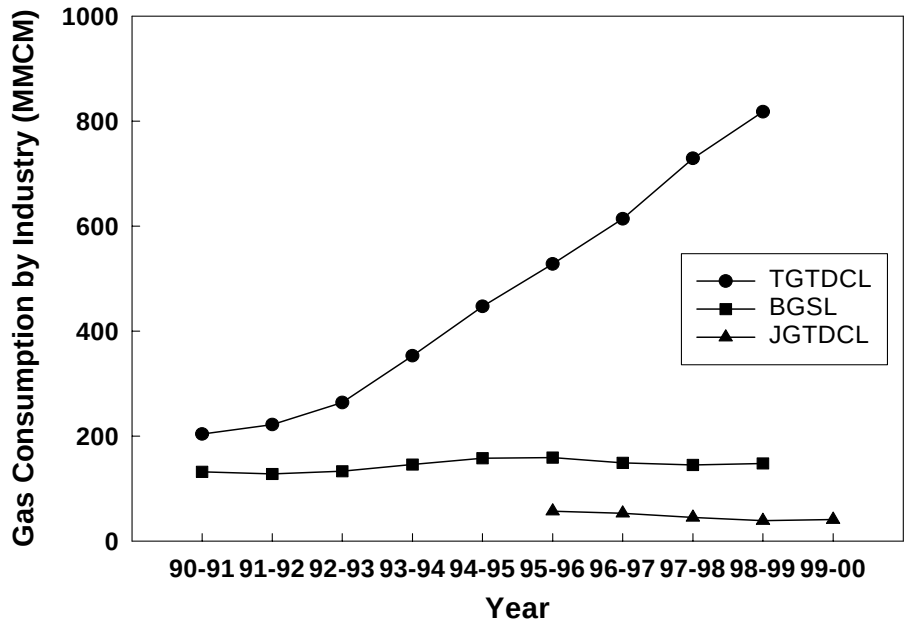
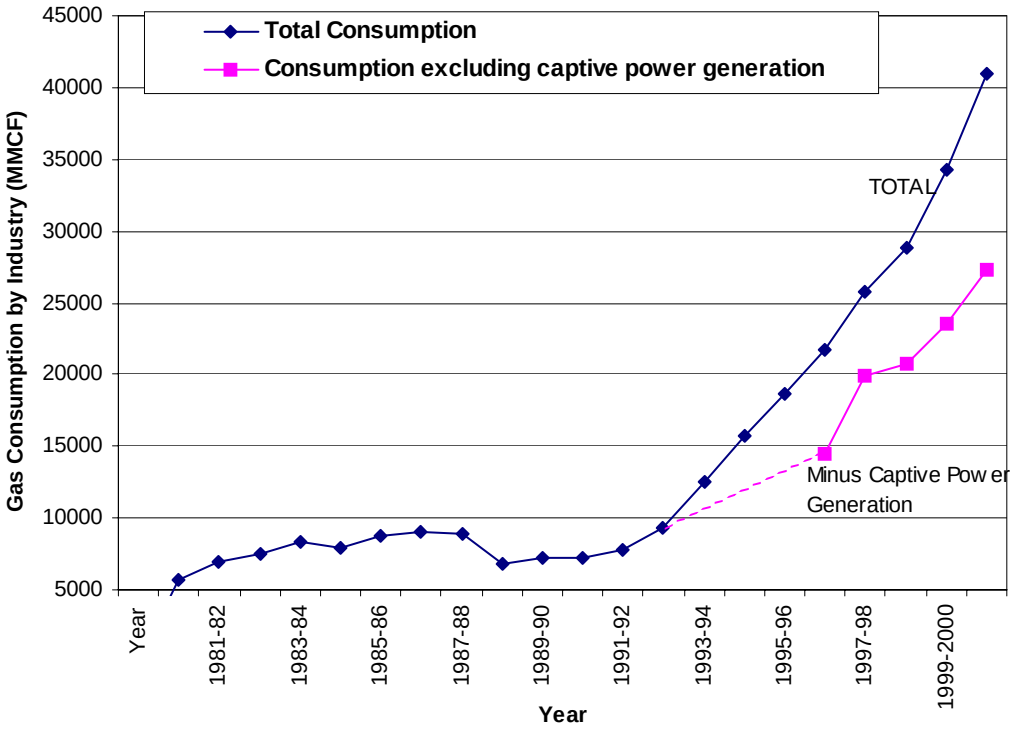


FIGURE 8.5: GAS CONSUMPTION BY INDUSTRY IN TITAS FRANCISE AREA
(Total and excluding captive power generation, 1980-2001)



The franchise areas covered by TGTDCL have shown steady growth during 1991-2000 and it will continue for a few years. One of the reasons for the growth is the installation of gas engine driven generators as captive power or stand-by power supply by RMGs, Textile, Ceramics, Pharmaceuticals and other manufacturing plants. It is reported that one company alone supplied more than 300 gas engine generators in the range 125-2000 KW in the past few years. There are more such suppliers. Figure 8.5 shows that 37.5 MMSCFD gas was consumed by the captive power generators out of total 112 MMSCFD. A number of recycle paper mills and cement clinker grinding plants in the franchise areas with captive power generation have come on-stream in the past few years.

Since the actual consumption in different franchise areas by the three older distribution companies are known, it would be useful to study the customers industry wise and uses of gas to understand the potential of this sector. This would provide a realistic basis for future planning of this sector.

The gas of Bangladesh contains more than 94% methane by volume. Its suitability as a feedstock for petrochemicals is not promising. It does not have technological edge over other raw materials used for petrochemicals worldwide and it is not considered as a potential raw material for petrochemical industry.

Commercial Sector and Seasonal Users

In 1998, the commercial sector used about 1.62% of the total gas consumption. The growth of this sector will remain slow. Similarly, the growth for the seasonal users will also remain slow.

IX. ALTERNATIVES FOR REVENUE FROM GAS UTILISATION (6, 15, 16, 27, 29)

The alternatives that can generate revenue from gas considered here would mean the export of a new end product or gas itself with or without change of form /phase. Its main purpose is to generate additional funds to develop this sector. These alternatives include:

Aluminum
Power
Fertilizer
Methanol
Petrochemicals
LNG (Liquefied Natural Gas)
GTL (Gas to Liquids)
CNG (Compressed Natural Gas)
Pipeline Export of Natural Gas

The alternatives dealing with LNG, GTL, CNG and Pipeline Export of Natural Gas result in the export of gas as it is with or without phase change. The production of fertilizer, methanol and petrochemicals results in new product based on gas as a raw material and fuel. The production of aluminum requires the import of the basic ore and gas is used as an energy source for electricity. Generation of Electric Power is the transformation of gas into electricity. Pipeline Export of Gas and Electric Power mean targeting one potential customer.

A number of studies have been undertaken considering above alternatives to establish the best option for monetising gas. Most of these studies have not considered the utilisation of the same volume of gas for each alternative. A clear picture in respect of investment size, marketing opportunities, and risk involved is lacking.

As far as Bangladesh is concerned the alternatives dealing with aluminum, methanol and petrochemicals are not promising at all. The alternatives based on CNG and GTL are not well proven technologically for the size of operation envisaged. However, in near future GTL may be a potential option if import substitution of the middle distillates is a consideration. We examine hereunder the alternatives: Fertiliser (urea), Power, LNG and Gas Export by pipeline.

Let us assume that 500 MMSCFD of gas will be used and each alternative is examined separately.

Fertilizer (Urea)
To utilise 500 MMSCFD gas to produce urea, we require 16 ammonia-urea complexes of the size of CUFL/JFCL. This will require an investment of about US$ 5 b. The total urea to be produced is about 9 million ton per year creating a glut in the world market. Currently the cost of gas used for producing urea is about US$ 1 per MMBTU (~1000SCF). The present world urea price does not look promising (US$ 100-130 per ton) to give an acceptable return.

Power
To utilize 500 MMSCFD gas for power generation we need to build power plants to generate 3500-4000 MW electricity and transmission systems. This will require an investment of about US$ 2.5 b in addition to the cost for transmission system. The return from such option has been reported to be discouraging considering the size of investment.

Liquefied Natural Gas (LNG)
To export 500 MMSCFD gas in the form of LNG we require LNG plant, export terminals, ships etc. This will require an investment of about US$ 2 b. The current LNG prices landed in Japan/India range from US$ 3.00 to 3.63 per MMBTU. After the deduction of costs due to LNG production, terminal, shipment and regasification from the price, the remaining margin does not look attractive when one considers the wellhead price of gas elsewhere.

Gas Export by Pipeline
To export 500 MMSCFD gas by pipeline over a distance of 1000 km we will require a 24-30 inch diameter pipeline system depending on the pipeline pressure that is to be certainly in excess of 1000 psig. This would require an investment close to US$ 1 b including gas compression stations and related facilities. If the export price of gas is US$ 2.50 per MMBTU (~1000 SCF), this option seems to have a better return compared to other options considered. But all related implications should be looked into in detail. Under the present circumstances, gas export can be considered as a short to medium term option and should be a part of the overall gas sector development plan.

This alternative will require a large number of agreements, MOUs and permits to implement the project and operation thereafter. Some of them are listed below:

1. Amendment of the existing PSC for gas export by pipeline
2. Wellhead Gas Purchase and Sale Agreement
3. Gas Transmission Agreement
4. Export Pipeline Agreement
5. Transboundary Gas Transmission Agreement
6. Border Gas Purchase and Sale Agreement
7. Permits for ROW, land acquisition, pipeline operation etc.

Bangladesh, today, does not have regulatory framework for undertaking the export of gas by pipeline and for subsequent monitoring and regulations. Moreover, issues concerning ownership of export pipeline (inside and outside Bangladesh), cost recovery, to whose account the export income to be deposited first and then its distribution, transfer of ownership etc. to be clearly understood with implications. Bangladesh needs to develop human resource to handle it.

Table 9.1 provides a summary of cost-benefit for these options for the utilisation of 500 MMSCFD gas considering the depreciation of investment over 12 years with borrowed money at 10% interest rate. These figures are indicative in nature and further refinement would be required for a decision considering related implications.

TABLE 9.1: SUMMARY OF COST-BENEFIT FOR VARIOUS OPTIONS
Basis: Utilisation of 500 MMSCFD gas for various alternatives

All costs are in million US $

Parameters	**Options**			
	Fertilizer (Urea)	**Power**	**LNG**	**Pipeline**
Capital Investment	5000	2500**	2000	1000
Volume/Quantity Of end products Per year	9,000,000 t 100 % capacity utilisation	$21x10^9$ kWh 60 % load factor of 4000 MW	155 BCF	182BCF
Elements of Cost of Production /yr				
Depreciation +Interest (Averaged over 12 years)	730	365	292	146
Gas	182	182	182	182
Operation, Maintenance + Others	100	80	30	20
Total cost/yr	1012	627*	477	348
Income/yr	1020 at $120/t	810 at 4c/kWh	465 at 3$/MSCF	456 at 2.5 $/MSCF

Assumptions:
Wellhead gas price: 1$/MSCF
Capital: all borrowed at 10% interest
Depreciated over 12 years
*Add to it cost for transmission
** Add to it additional investment for transmission

X. IDENTIFICATION OF AREAS FOR RESEARCH IN GAS SECTOR

Actual consumption of gas by different sectors, projection of demands by various studies and plan documents, estimation of gas reserves and potential by various studies, and operation of the IOCs during the past five years have given rise to a number of issues for further study and research. This will help to understand the gas

sector considering diverse viewpoints and its contribution to the country's resource and economic growth. The promising areas for research and studies include:

a. Study of gas consumption growth on sectoral basis to project future demands
b. Reserves estimate based on actual well testing and appraisal well
c. Impact on this sector if IOCs abandon their activities in Bangladesh
d. Implication of export of gas and Bangladesh's preparedness to undertake it
e. Other related issues arising out of PSCs

Study of Gas Consumption Growth on Sectoral Basis to Project Future Demands

We have at our disposal data for the consumption of gas by different sectors for a time horizon extending over thirty years. Past trends will provide us to understand how the individual sector grows and issues that influence the sector. It will be interesting to learn how the individual sector has contributed to the growth of GDP over the years considering its own growth. How does the growth of sectors such as electric power generation and industry using gas influence each other? Since the different gas distribution companies serve defined franchise areas, it will be possible to predict the demand pattern region wise and sector wise. This will provide planners with growth trends and potentials of different sectors and areas of the country where to expand gas network to make our planning and intervention more realistic and attainable.

Reserve Estimates Based on Actual Well Testing and Appraisal Wells

Estimation of gas reserves in Bangladesh is mostly based on the data obtained during the production testing after completion of the exploratory well. In most cases, it is not supported by additional appraisal wells. Appraisal wells require funds. Pressure testing at certain intervals is not possible for lack of additional wells in the fields to support the suspension of production by the well during testing. For some fields technical constraints associated with well completion make the testing difficult.

Estimation based on geological formation of the reserves is indicative of the reserve potential. Actual data based on more advanced techniques such as 3-D survey can help to estimate the size of the reserves and its potential for growth. Especially the production of water and sand in some of the fields, namely- Bakhrabad, Chhatak, Kamta and Feni before a sizeable quantity of gas could be produced makes the recoverable gas reserves estimate doubtful. Based on the field data it is desirable to estimate the reserves of the more potential fields and to ascertain what additional data are required to support those estimates.

Impact on This Sector if IOCs Abandon Their Activities in Bangladesh

IOCs under PSCs have invested in this sector to generate revenue for themselves and Petrobangla as well as to invest a part of their profit to strengthen their position as dynamic producers of oil and gas. If the IOCs are unable to produce gas and market it, they will be frustrated with their operations in Bangladesh. The worst scenario is that they would cap the wells and leave or dispose their assets.

Since Bangladesh does not have funds or alternative resources to invest in exploration and development, the potential for developing this sector looks bleak. Some studies would be useful to understand the implications of abandoning their operations in Bangladesh, especially Bangladesh's opportunity to attract FDI in particular for risky ventures and also to find out ways and means to avoid it.

Implication of Gas Export and Bangladesh's Preparedness to Undertake it

Although the PSCs now in operation do not have the provisions of gas export by pipeline; export in other forms including LNG is possible. Whatever may be the form of export, Bangladesh has not yet decided its methodology and yardstick about how to measure the potential of an opportunity and compare with available options on equal basis.

Moreover, to start with, the country does not have regulatory framework to administer the operations of IOCs and PSCs whether it is for approving a plan or a budget or operation. The country is not fully aware of the implications of different contracts/agreements to be signed. The whole issue needs to be studied and understood to appreciate the implications and their impact on Bangladesh.

Study on the Involvement of IOCs and Preparation of PSCs in the 80s and 90s

For establishing transparency in this sector and to have public trust in our governance, it is much needed to research into the following:

a. Why the IOCs were invited to Bangladesh especially in the 80's and 90's.
b. How PSCs were prepared and approved.
c. Bid preparation and invitation process
d. Bid evaluation criteria.
e. Negotiation terms with IOCs.
f. Why the Jalalabad Field was given to Occidental.
g. Why the Haripur Oil Field was not developed properly.
h. How Schimittar got into hydrocarbon exploration in Bangladesh.
i. Why Petrobangla failed to monitor the operations of IOCs under PSC.
j. Why all the blocks were listed for PSC.
k. Why the government did not make the report public on the Magurchhara well blow out and strike a deal for compensation.
l. How the price of gas to be purchased from IOCs for domestic market was decided.
m. Financial implications specially impact on the country's foreign currency reserve due to payment to IOCs in foreign currency.
n. Whether we have got the required regulatory framework to deal with the PSCs.

All these issues deserve to be looked into in greater detail to understand and appreciate the past and present situation of this important sector for its development in the future.

Any Other Issue

As the researchers endeavour through the issues mentioned above they will encounter issues on the fringes for further study. The studies will be multidisciplinary in nature involving engineering, geology, economics, law, environment and politics. Topics will be selected area- wise as mentioned above. These will certainly strengthen our capacity to understand this sector and its potential for growth and expansion with considerable impact on our quality of life.

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