

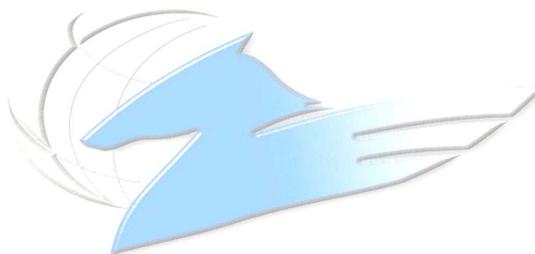
FINAL REPORT

FOR

THE FEASIBILITY STUDY FOR SETTING UP

A STRADDLE PLANT FOR NGL EXTRACTION &

FRACTIONATION AT ASHUGANJ



PEGASUS

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PREFACE

Pegasus International Sdn Bhd, Malaysia has been commissioned by Hydrocarbon Unit, Energy & Mineral Resources Division to prepare a Feasibility Study for the Setting Up of A Straddle Plant for NGL Extraction & Fractionation at Ashuganj.

The aforesaid feasibility study has been made by a team comprising of engineers, financial analyst and officers of Pegasus International at Dhaka Office. Officers and staff of Hydrocarbon Unit, under MEMR timely assisted the team to perform the study.

In keeping with the objective of the potential uses of NGL being extracted and fractionated at Ashuganj, the scope of work of this project as per the Terms of Reference is as follows:

- 1) Determine both proven and recoverable sources of NGL and estimates of the most likely additional NGL, which may be available as a result of contemporaneous exploration.
- 2) Determine extractable amount of NGL (including ethane) towards preparation of a techno-economic model to determine the feasibility of setting up a straddle plant for NGL Extraction including Fractionation which could process NGL from extraction plant.
- 3) Prepare conceptual design, cost estimates, economic analyses and opportunity cost comparisons for Potential uses of NGL for Petrochemical i.e. NGL mix feed ethylene cracker with polyethylene and polypropylene plants, olefins plants, etc.
- 4) Recommend other alternate use of NGL (including aromatics, methanol and derivatives) which may be economically competitive as well as attractive.
- 5) Recommend the best strategic use of the NGL components based on opportunity cost comparison.

- 6) Recommend prices for all products produced considering competing imported products and the potential for export and comment on the economic advantages and disadvantages of applying protective tariff.

One of the approach/methodology that the Pegasus team members along with a representative of Hydrocarbon Unit adopted was to visit the gas fields of SGFL, BGFCL & including Chevron's gas fields in greater Sylhet zone to collect require data pertinent to production operation, projection & reserves. Also, the team collected some latest required data from Petrobangla.

In this regard, we like would like to thank the officers and staff members of Petrobangla and its companies & the Hydrocarbon Unit for whose help and encourage drove us to complete the aforesaid feasibility study.

We call it "straddle plant" because straddle means two or more sides in one arbor to work in one operation. On the other hand in this project, a straddle plant is a sophisticated natural gas processing plant sitting along the side of the North-South natural gas transmission pipeline coming from two or more companies. Gas is extracted from the pipe line, stripped of its natural gas liquids (**NGLs**--NGL + condensate) to produce ethane (C₂), propane (C₃), iso-butane (i-C₄), normal butane (n-C₄) and natural gas condensate (C₅₊). Once the process has been completed, the gas is then re- and then re-injected back into the main gas transmission pipeline. Currently, GTCL has an on-going project to install mainline gas compressor at Ashuganj to boost up the gas flow through the existing 30 inch pipeline from the current flow rate up to 1500 mmscfd.

In the conceptual schematic process flow diagram (**Annexure-88**) of the plant, it is shown that the assumed minimum feed gas from Chevron's Bibiyana gas field during the tenure of the plant shall be 350 mmscfd (more but sustainable will be better) plus 650 mmscfd (minimum) from BGFCL's Habiganj gas field plus 300 mmscfd (minimum) from SGFL's Rashidpur/Kailashtilla/Haripur gas fields to give a total mixed gas feed of 1,300 mmscfd (1.30 bscfd). Also, an assumed mixed feed condensate at the rate of a minimum of 6,200 barrels per day from Kailashtilla, Bibiyana, Moulavibazar, Rashidpur,

Sylhet (Haripur) & Beanibazar is required. Assumed required raw feed condensate-gas ratio = 4.75.

After extraction of the **NGLs**, the remaining quantity will be 1.2545 bscfd and this dry gas will be re-injected to the North-South sales gas transmission pipeline. Hence, the cost of 0.0455 bscf/per day or 15.015 bscf/year, will have to be paid to Petrobangla by the straddle plant authority if this project shall be executed in the future.

For the requirement of the straddle plant, 6,200 bpd mixed condensate will be taken from the GTCL's 6" North-South condensate pipeline as this pipeline is currently used for transporting condensate from the gas fields in Sylhet to RPGCL's Ashuganj storage tanks.

The team is optimistic that the gas as well as the **NGLs** production will increase in the near future. However, if mixed **NGLs** is not available from the 6" (N-S) condensate pipeline then, the government may have to import the **NGLs** for this plant, otherwise the feasibility study may not be viable. However, to create a clear understanding regarding the possible high-value marketable products of the straddle plant complex, a brief description of each of the following products was made as per Annexure 16 - 81: polyethylene, polypropylene, precipitation naphtha, mineral turpentine, BTX aromatics (benzene, toluene & xylene - used as solvents), octane number booster/additive, cetane number booster/additive, motor spirits, high speed diesel, kerosene, LPG (liquefied petroleum gas), methanol, formaldehyde and ammonia .

The prices of the petroleum products have been obtained from the Bangladesh government gazette and from present open market. It is but fair to say, that the estimation of prices for the machineries & equipment in this feasibility study has been estimated from the book "Strategic Gas Utilization study for the People Republic of Bangladesh", authored by SH Lucas & Associates. The products from this proposed straddle plant in Ashuganj will minimize the import of the said products even if necessary the product may be exported to the SAARC & other Asian countries thereby saving precious foreign exchange. Therefore, Bangladesh will be able to safely earn the potential amount of foreign currencies.

Based on the financial analysis for the “best strategic use of the **NGLs**”, the following scenarios were observed during the feasibility study:

Scenario 1: If the capital cost, selling price of finished products and price of raw materials remain constant, then IRR will be 28%.

Scenario 2: If the sales revenue and cost of goods sold remain constant & capital cost of the project increases by 20%, then IRR will be 24%.

Scenario 3: If the selling price remains constant, capital cost increases by 20% and the cost of goods sold goes up by 10%, then IRR will be 22%.

Scenario 4: If the price of the raw materials remains constant, selling price of the finished products goes down by 10% and the capital cost of the project goes up by 20%, then IRR will be 20%.

Scenario 5: If at the time of project implementation the total capital cost of the project goes up by 20%, accompanied by a 10% decline in the selling price and then a 10% increase in the price of raw materials, which are the worst conditions, then IRR will be 18%.

1. INTRODUCTION TO THE FEASIBILITY STUDY FOR SETTING UP A STRADDLE PLANT FOR NGL EXTRACTION AND FRACTIONATION AT ASHUGANJ

Pegasus International Sdn Bhd, Malaysia has been commissioned by the Hydrocarbon Unit, Energy & Mineral Resources Division to prepare a Feasibility Study for the Setting Up of A Straddle Plant for NGL Extraction & Fractionation at Ashuganj.

To assist our Malaysia office in carrying out this feasibility study, Pegasus International – Bangladesh Office, has been appointed as the local supporting office for this project. The local office provides us with useful insight into several of the issues relating to this feasibility study. Moreover, the local office assisted our Malaysia office in the mobilization of the local manpower component of this project as per the requirement of the Contract.

In accordance with the Terms of Reference of the Contract, the Interim Report is the second deliverable of our assignment. This Interim Report highlights the progress that we have made during the past six (6) weeks since the project kick-off on the 8th of November 2009. It is structured on the following lines:

- **Section 2: OBJECTIVE OF THE FEASIBILITY STUDY FOR SETTING UP A STRADDLE PLANT FOR NGL EXTRACTION & FRACTIONATION AT AHSUGANJ**
- **Section 3: TERMS OF REFERENCE (TOR) & SCOPE OF WORK**
- **Section 4: SITE VISITS, DATA COLLECTION, SITE VISIT REPORTS AND ATTACHMENT OF THE DATA COLLECTED HERETO**
- **Section 5: ACKNOWLEDGEMENT, REFERENCES USED IN PREPARING THE FEASIBILITY STUDY REPORT FOR SETTING UP OF A STRADDLE PLANT FOR NGL EXTRACTION AND FRACTIONATION AT ASHUGANJ**
- **Section 6: GLOSSARY AND ABBREVIATIONS**
- **Section 7: QUERIES AND REPLIES DURING THE PRESENTATION OF THE FEASIBILITY STUDY FOR SETTING UP A STRADDLE PLANT FOR NGL EXTRACTION & FRACTIONATION AT ASHUGANJ AT THE HYDROCARBON UNIT CONFERENCE ROOM ON APRIL 18TH 2010**

2. OBJECTIVE OF THE FEASIBILITY STUDY FOR SETTING UP A STRADDLE PLANT FOR NGL EXTRACTION & FRACTIONATION AT ASHUGANJ

The main objective of the feasibility study is to determine the viability – both technical and economic for Setting up A Straddle Plant for NGL Extraction & Fractionation at Ashuganj considering NGL recovery and its potential uses in Petrochemical production, Fuel Additives & others.

Several downstream industries, i.e., petrochemical industries, transport and other industries will make use of the by-products of the straddle plant complex.

3. TERMS OF REFERENCE (ToR) FOR THE FEASIBILITY STUDY FOR SETTING UP A STRADDLE PLANT FOR NGL EXTRACTION & FRACTIONATION AT ASHUGANJ

In keeping with the objective of the potential uses of NGL being extracted and fractionated at Ashuganj, the scope of work of this project as per the Terms of Reference is as follows:

- 7) Determine both proven and recoverable sources of NGL and estimates of the most likely additional NGL, which may be available as a result of contemporaneous exploration.**
- 8) Determine extractable amount of NGL (including ethane) towards preparation of a techno- economic model to determine the feasibility of setting up a straddle plant for NGL Extraction including Fractionation which could process NGL from extraction plant.**
- 9) Prepare conceptual design, cost estimates, economic analyses and opportunity cost comparisons for Potential uses of NGL for Petrochemical i.e. NGL mix feed ethylene cracker with polyethylene and polypropylene plants, olefins plants, etc.**
- 10) Recommend other alternate use of NGL (including aromatics, methanol and derivatives) which may be economically competitive as well as attractive.**
- 11) Recommend the best strategic use of the NGL components based on opportunity cost comparison.**
- 12) Recommend prices for all products produced considering competing imported products and the potential for export and comment on the economic advantages and disadvantages of applying protective tariff.**

3.1 Determine both proven and recoverable sources of NGL & estimates of the most likely additional NGL, which may be available as a result of contemporaneous exploration.

Bangladesh is a natural gas-producing country. It is a major prime mover of the Bangladeshi industry. Natural gas has a wide variety of uses, from power generation to petrochemical production to transportation to domestic consumption.

At present, there are twenty three (23) gas producing fields located mainly in the northeastern part of the country and each and every gas field has its own system of processing the raw field gas and then piping the sales gas to the main line sales gas transmission grid that runs from north to south of the country (please see map shown below) that supplies the gas to the customers. Some gas fields send their sales gas to a separate transmission pipelines that do not blend with the north-south gas transmission pipeline. Some gas fields produce little natural gas and some are big producers. More gas fields will be put on-line in the near future as the government agency, which has taken the responsibility of exploring and finding more gas in the country, is showing its aggressiveness to search for more gas to sustain the country's needs for natural gas.

Natural gas itself, when it comes to the surface contains liquids and little sand particulates. The liquids contain hydrocarbons having a high value in the market. Hence, they must be separated from the gas and their use maximized along with the gas for the benefit of the country.

Raw gas coming from the gas fields undergo gas processing in their respective fields of origin. In Bangladesh, the gas dehydration and liquids removal processes done in the field include the following: glycol (Tri-Ethylene Glycol or TEG) dehydration type, low-temperature extraction type (LTX), silica gel dehydration type, glycol (TEG) dehydration with turbo expander type and the more sophisticated molecular sieve turbo expander type (MSTE) of gas processing. Each of these processes has its own limitations and that the sales gas quality from each one of the gas-producing fields that they pipe into the main line gas pipeline depend on what specific process it is using. None of these existing gas field processes, however, can deeply extract more liquids (ethane, propane, iso-butane, n-butane, pentanes) from the gas to a point whereby only methane & a little ethane will go to the main sales gas pipeline and the high-value products separated as well as utilized,

instead of burning these valuable liquids in the consumer industries without any additional value in return.

Because of this very reason, this feasibility study is made to determine the feasibility of extracting more liquids from the mainline sales gas in Ashuganj prior to its utilization in the consumer industries to earn money as well as reduce the greenhouse gas emissions.

As of this report, figures from the Hydrocarbon Unit, Energy & Mineral Resources Division, Ministry of Power, Energy & Mineral Resources' " Monthly Gas Reserve and Production", showed an average daily production of 1,873.52 mmscfd (December, 2009). Four (4) years ago (December 2006), the average daily production was at 1,382 mmscfd. These figures clearly suggest the growing consumption of natural gas in the country. The more gas produced and consumed without extracting the high-value liquids, the more losses would that be to Bangladesh and its people because we are burning the scarce, high-value liquids with no added benefit. Moreover, a lot of greenhouse gases are generated and emitted there from for nothing.

Hence, this feasibility study for setting up a straddle plant for NGL Extraction & Fractionation at Ashuganj is made for the aforementioned purpose.

What is a "Straddle Plant"?

A "Straddle Plant" is just a sophisticated natural gas processing plant. It is called "Straddle Plant" because it sits along side of natural gas transmission pipelines. Here, natural gas is extracted from the pipeline, stripped of its natural gas liquids (**NGLs**) to produce ethane (C₂), propane (C₃), iso-butane (i-C₄), normal Butane (n-C₄) and natural gas condensate (C₅₊). Once the process has been completed, the gas is then recompressed and then re-injected back into the main gas transmission pipelines. Pictures of an existing straddle plant found in North America are found in page no. 8 & 9.

In this project, the term natural gas liquids or "**NGLs**" are liquid hydrocarbons that are recovered from natural gas in gas processing plants, and in some cases, from field processing facilities. **NGLs** include ethane, propane, butanes, pentanes and heavier hydrocarbons components. In the reservoir, these hydrocarbons exist as gases and whenever they reach the surface separators, the heavier components condense and liquefy due to the reduction of pressure and temperature. Hence they are called **condensates** or natural gasoline.





3.1.1 Current Natural-Gas-Producing Fields in Bangladesh

3.1.1.1 Gas Fields Operating Under PetroBangla (NOC's)

- | | | |
|------------------|----------------|-------------------|
| i) Titas | ii) Habiganj | iii) Narshingdi |
| iv) Fenchuganj | v) Sylhet | vii) Kailashtilla |
| viii) Beanibazar | ix) Rashidpur | x) Kamta |
| xi) Meghna | xii) Bakhrabad | xiii) Salda Nadi |
| xiv) Begumbanj | xv) Shahbazpur | xvi) Seimutang |

3.1.1.2 Gas Fields Operating Under Independent Oil Companies (IOC's)

- | | | |
|--------------|---------------|-------------------|
| i) Bibiyana | ii) Jalalabad | iii) Moulavibazar |
| iv) Sangu | v) Kutubdia | vi) Bangura |
| vii) Chattak | viii) Feni | |

During a visit to Ashuganj on **November 17, 2009** (please see section on site visit & site visit report), the combined daily sales gas production scenario of both NOC's & IOC's from the SCADA system amounts to **1.89389 billion standard cubic feet per day (Bscfd)**. Of this amount, 1.13471 bscfd passes through the 30-inch main North-South gas pipeline distribution system in Ashuganj. This is today's maximum flow at current system pressure of the North-South main gas pipeline as per SCADA. The remaining balance of 0.75918 bscfd (on that specific date alone) passes through the Titas, Bakhrabad & Jalalabad mainline sales gas distribution pipelines.

Currently, GTCL has an on-going project to install mainline gas compressors at Ashuganj to boost the gas flow through the 30-inch pipeline from current flow rate up to 1,500 mmscfd after the successful installation & commissioning of those gas compressors.

3.1.2 Natural Gas Production in All Currently Producing Gas Fields in Bangladesh

A graph showing the trend of the monthly gas production for all gas-producing fields for the year 2009 is as follows:

Graph 1

Year 2009
Monthly Gas Production
(Bscf vs Month)

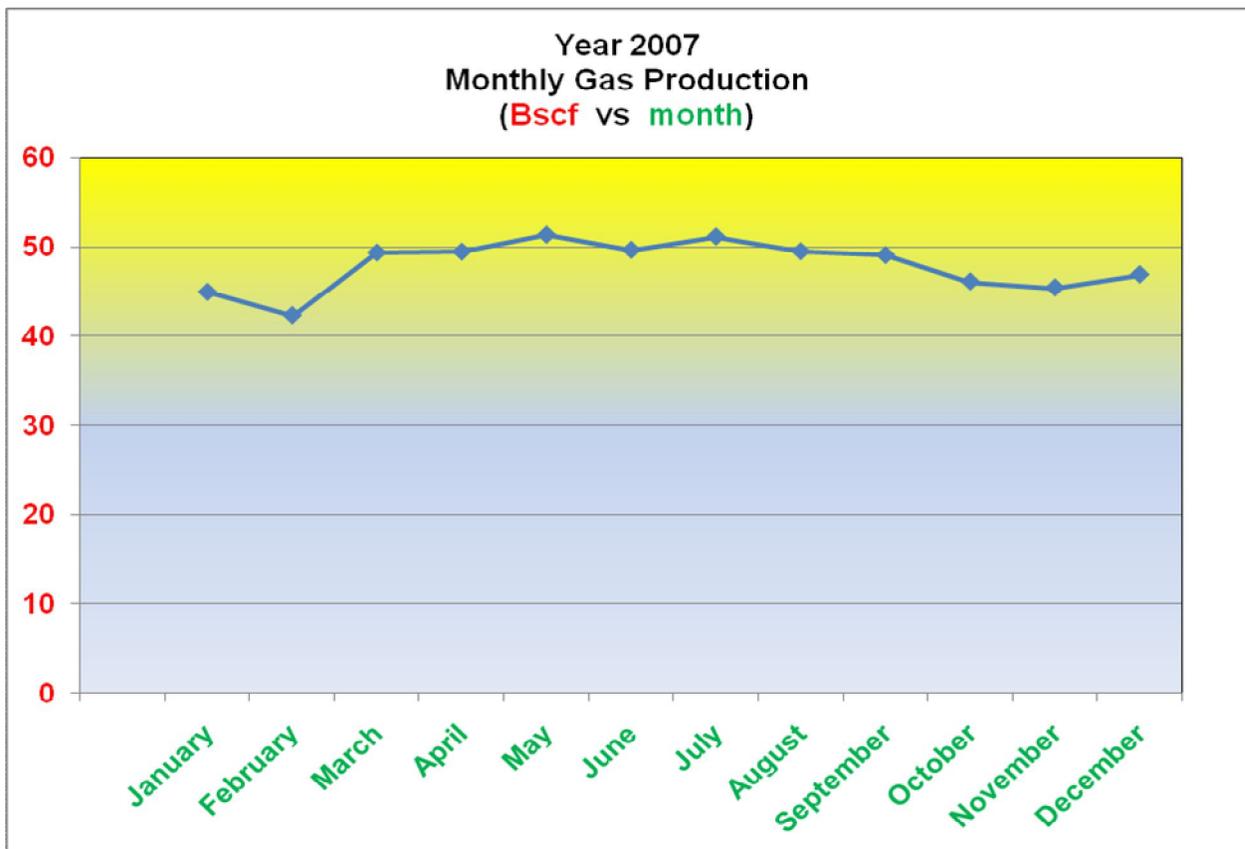


And for the previous four (4) years, 2005 – 2008, the monthly gas production graphs are as follows:

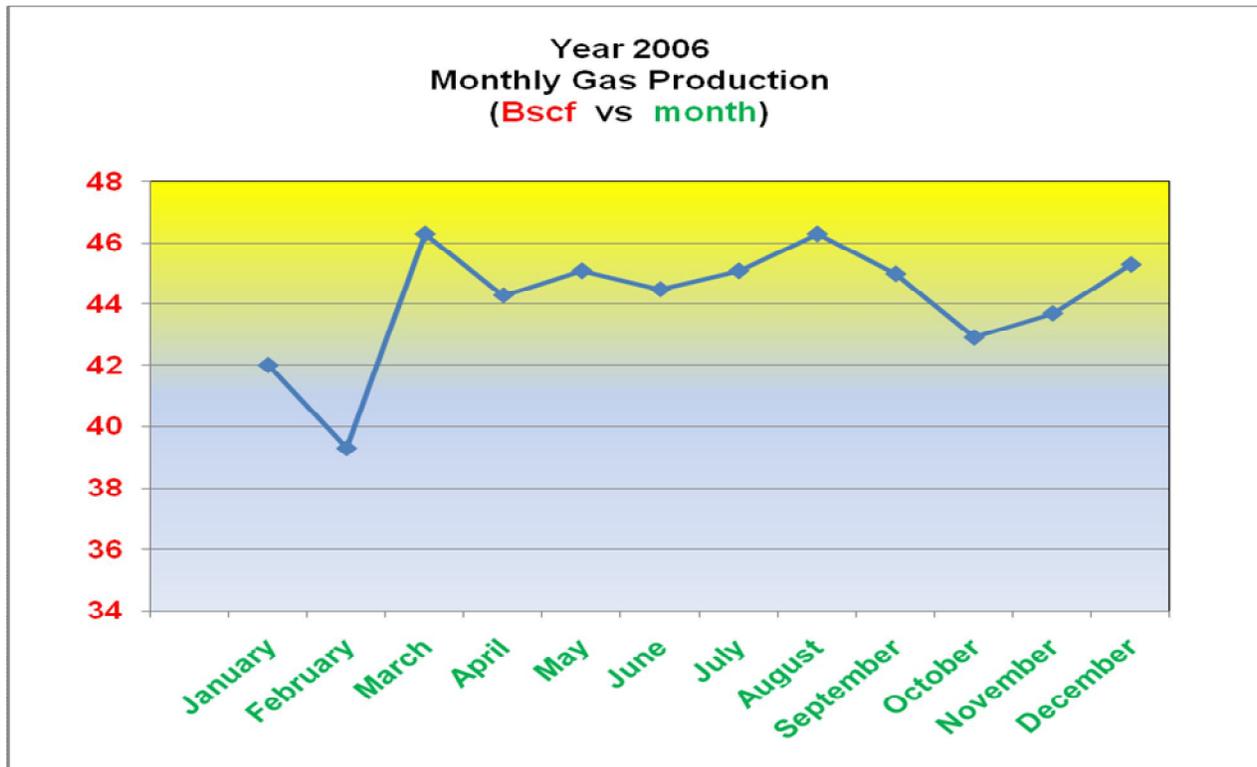
Graph 2



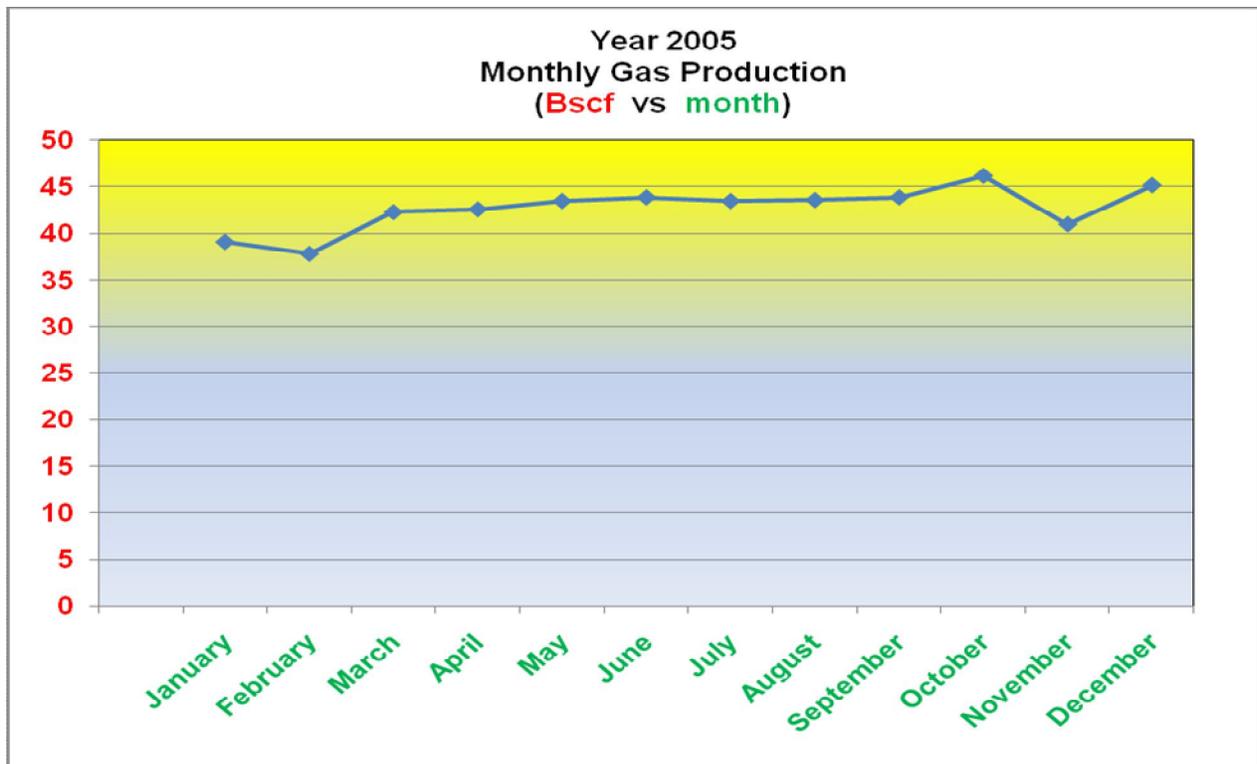
Graph 3



Graph 4

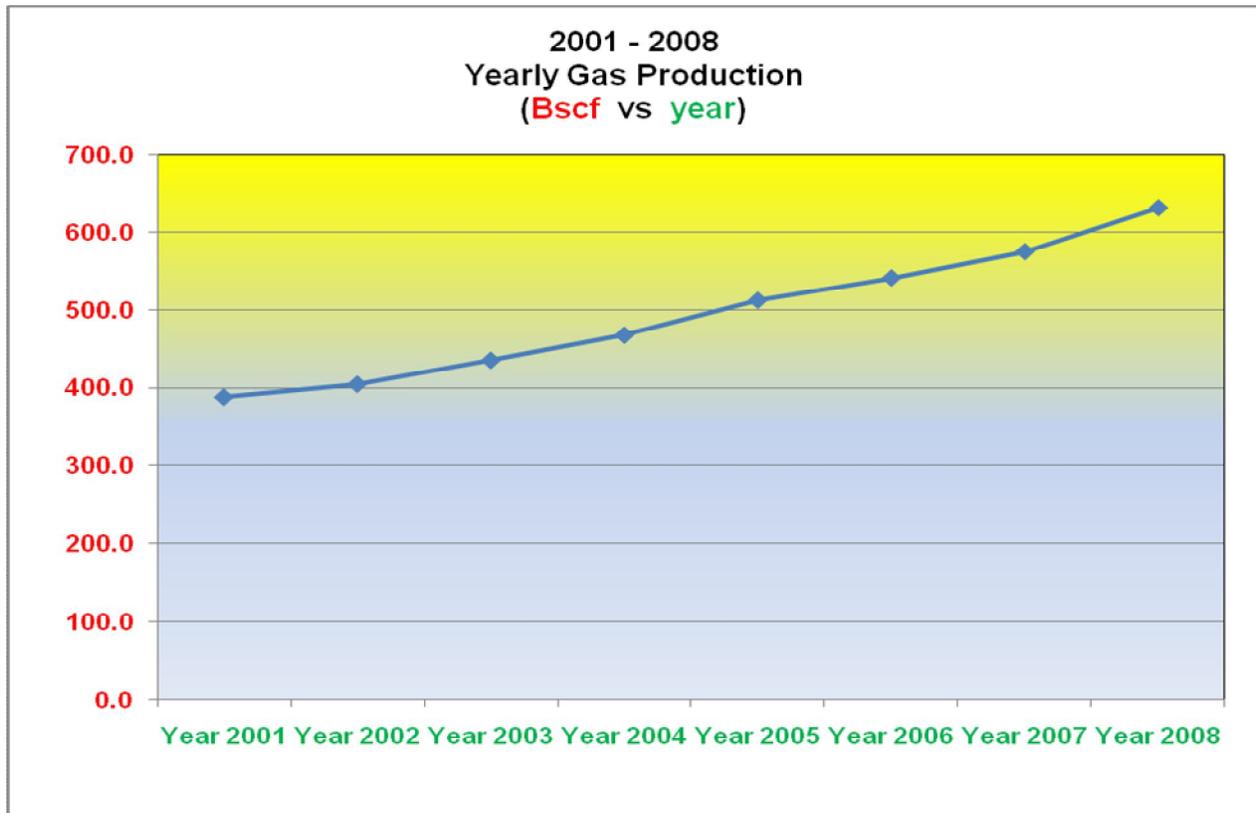


Graph 5



Further, the yearly gas production graph is as follows:

Graph 6



In preparing graph nos 1- 6 above, the figures were collected from the Hydrocarbon Unit, Energy & Mineral Resources Division & Petrobangla.

It is very clear from the above graphs that the gas production in Bangladesh is going up year after year, i.e., from **388.3 billion standard cubic feet per annum (bscfa)** in 2001 to **632.0 bscfa** in 2008. For the year 2009, complete year-end data is under process and it is expected that the gas production has increased too. This is an indication that the gas demand in Bangladesh is increasing.

In their respective gas fields, raw gas from the wellheads undergo primary gas processing and the sales gas, which still contains high-value light natural gas liquids that were not extracted from the gas field's primary processing unit, is sent to the mainline gas distribution pipeline.

There are several mainline sales gas distribution pipelines in Bangladesh, namely: GTCL's (Gas Transmission Company) 30-inch North-South in Ashuganj, TGTDC's (Titas Gas Transmission & Distribution Company Limited) 30-inch main line transmission pipeline in Ashuganj, JGTDSL's (Jalalabad Gas Transmission & Distribution System Limited) 8-inch main transmission pipeline in Sylhet. The consumers of the sales gas are the electric generation industry, fertilizer industry, non-bulk consumers (CNG transport vehicles, residential homes/buildings & commercial establishments including restaurants, bakeries, hotel kitchens, etc). The biggest consumer-the electricity industry extract energy from the sales gas by burning the gas in their boilers (for gas-fired steam turbine power plants) to generate steam to run the steam turbines which in return drives the generator to generate electricity or in the combustion chambers (for Combustion Gas Turbine Power Plants & Combined-Cycle Combustion Gas Turbine Power Plants) to run drive the turbines to generate electricity while collecting & recycling heat from the very hot exhaust gases and generate steam from the HRSG, thereby burning the light natural gas liquids that were not extracted from the sales gas. The next biggest consumers-the fertilizer industry, feed the sales gas to the gas reformers using high temperature & pressure steam to generate synthesis gas & convert the gas in their processing units to produce ammonia and then finally urea fertilizer. Same thing, the light natural gas liquids entrained in the sales gas is "reformed" without benefit for the government.

As the consumption of natural gas goes up, so does the burning of precious light natural gas liquids go up. And day by day, year-after year, Bangladesh and its people are losing precious natural resources through burning without additional values since the gas is sold and paid in volume only.

3.1.3 Current Natural-Gas-Liquids-Producing Fields in Bangladesh

All of the above-mentioned gas fields produce natural gas liquids in varying amounts. Some gas fields such as Kailashtilla, Beanibazar & Jalalabad produce large amounts of **NGLs** (NGL + Condensate) per unit quantity of raw wellhead gas and are therefore considered rich in **NGLs**. Other gas fields such as Chevron's Bibiyana & Moulavibazar & Tullow's Bangura produce medium-size quantity of **NGLs** per unit quantity of raw

wellhead gas, while others produce very little natural gas liquids (mostly heavy condensate) since their gas is considered “dry gas”.

IOC's such as Chevron, produce large amounts of condensates although their condensate-to-gas ratio is less than those of Kailastilla & Beanibazar gas fields. This is because they are currently the largest IOC gas producer in Bangladesh & they are capable of sending 650 - 700 mmscfd of sales gas to the main sales gas pipeline. Their main bottleneck, Chevron says, is the capacity of the 30-inch Rashidpur to Ashuganj pipeline to absorb this higher capacity.

3.1.3.1 KAILASTILLA GAS FIELD

Kailastilla Gas Field belongs to Sylhet Gas Fields Ltd (SGFL). The existing Molecular Sieve Turbo Expander (KTL-MSTE #1) plant, located at Golapganj, Sylhet, was originally designed to process 90 MMscfd of raw gas and with a yield of some 1,818 bpd of NGL. At present, the plant operates in the JT (Joule Thompson) mode to recover the NGL from the de – ethanizer tower. Present gas production is about 69 MMscfd with a pressure of 1128 psia and NGL production is about 980 bpd. Of this, about 380 to 500bpd goes to the KTL LPG plant, hence, about 510 bpd of condensate could be sent to Ashuganj through 6-inch north-south pipeline. If the plant were to be operated in Turbo expander mode, NGL production would be more & that would be about 1,200bpd.

3.1.3.2 RASHIDPUR GAS FIELD

SGFL's Rashidpur Gas Field is currently producing only 49 mmscfd gas from its existing five (5) gas wells. Corresponding condensate production is 50 bpd only. SGFL has initiated projects to fast tract & increase gas production capacity at Rashidpur by work-over of gas well nos. 2 & 5. They have a program to drill another gas well too, thereby increasing the total sales gas production by at least 40 mmscfd and corresponding condensate production will increase accordingly. Currently, a 3-D seismic survey is on-going to assess the realistic & internationally-accepted gas reserves in the gas field.

3.1.3.3 SYLHET GAS FIELD (HARIPUR)

SGFL's Haripur gas field is not producing so much gas & condensate at the moment because there is no gas in well nos. 1, 2, 3, 4, 5 & 7. Only a little quantity of gas is produced from gas well no. 6. Gas production is scheduled to increase to 8 mmscfd when the work over of Sylhet-7 within the next couple of months, in which about 24 bpd condensate will be the projected production. The amount will depend on the existing silica gel gas dehydration processing plant and thus NGL production will rise accordingly.

3.1.3.2 BEANIBAZAR GAS FIELD

SGFL's Beanibazar Gas Field presently produces 15 - 16 MMscfd gas from 2 wells. There is a silica gel gas processing plant & the corresponding condensate production is 250 bpd. It is a rich gas, i. e., CGR is about 16. Here at present, the sales gas goes to JGTDSL. Previously, the sales gas went to the north-south gas pipeline but because of a bottle-neck pressure which is not enough to connect with N-S pipeline, it was sent to the JGTDSL.

3.1.3.2 BIBIYANA GAS FIELD

Bibiyana Gas Field is one of the field of IOCs which is being operated Chevron Bangladesh Block 12 Ltd. There are a total of 14 gas wells in Bibiyana gas field & 7 nos. of gas wells are producing gas & condensate. It is under IOCs block no. 12. They dehydrate the gas with TEG- glycol gas processing plant. From that field they can produce 650 to 700MMscfd gas & supply to the North-South gas pipe line.

However, since there is pipe line bottleneck capacity, Chevron cannot pipe 700 mmscfd gas to the North-Side pipeline at the moment as the limitation of the pressure along the pipe line is already reached. Installation of gas compressors at Muchai-Rashidpur area will boost the 30-inch capacity so that Chevron can pipe at least 700 mmscfd after the successful installation of the said gas compressors.

Presently, the average condensate-to-gas ratio of all gas wells in Bibiyana is about 5.58. About 3,903 bpd average daily condensate is produced within the current average gas production (630 mmscfd). Bibiyana gas field currently supplies the Rashidpur Condensate Fractionation Plant.

Chevron has plans to increase gas production & condensate capacities by drilling new gas production wells in the near future.

3.1.3.3 JALALABAD GAS FIELD

Chevron Bangladesh Block-13 & 14's Jalalabad Gas Field is located within Lakatura Tea estate at Sylhet. At present, there are four (4) nos. gas wells producing gas from this field. Sales gas volume of this field is about 180 MMscfd & the maximum capacity is 230 mmscfd. Condensate production is about 1,500 bpd. Efficiency of the plant is 99.9%. Condensate-to-gas ratio is 8.50. Chevron is planning to drill two (2) more gas wells in the near future to enhance production. Currently, all sales gas produced from Jalalabad gas field is piped through the 8-inch Jalalabad Gas Transmission & Distribution pipeline. At present, a portion of the condensate from Jalalabad gas field is pumped to RPGCL's Kailashtilla Fractionation Plant # 2 at Kailashtilla, Golapganj, Sylhet. Ashuganj likewise takes in some of the condensate from time to time & the rest goes to Rashidpur condensate fractionation plant at Rashidpur. It is also known that Rashidpur condensate fractionation plant will enhance its production capacity, hence, it will require more condensate from Chevron fields in the future.

It may be mentioned that we learned from the team's previous visit to Chevron that they will install an NGL Recovery plant at Bibiyana gas field. However, the team is hoping that gas & **NGLs** (NGL + Condensate) production will increase such that a justification for setting up a viable straddle plant for NGL extraction and fractionation at Ashuganj will be realized.

3.1.3.4 MOULAVIBAZAR GAS FIELD

Moulavibazar Gas Field is one of the fields of Chevron Bangladesh, under block – 13 & 14. It is located near Kalapur, Sreemongal. There are 3 nos. of gas wells now producing gas & condensate from Moulavibazar. Its produced gas is comparatively dry. They are using glycol de-hydration plant to separate the liquids from the gas. From this field, 60 mmscfd of sales gas is being supplied to the Jalalabad main transmission & distribution pipe line.

They have plans to drill more gas wells to increase production, and as such, more NGL can be extracted from the N-S pipe line gas at Ashuganj for a straddle plant, if ever.

3.1.3.5 1st SPECIAL MENTION: ASHUGANJ: POSSIBLE SITE MENTIONED IN THIS FEASIBILITY STUDY FOR SETTING UP A STRADDLE PLANT FOR NGL EXTRACTION & FRACTIONATION

Ashuganj upazila, located in Brahmanbaria District, is a very strategic area for projects such as a straddle plant complex. Situated at the North-Western part of Brahmanbaria District, it lies very close to the Meghna River and as such it has a river port where ships or crude oil tankers can load and offload petroleum products.

A sizable piece of land, measuring approximately 21 acres, was acquired by Petrobangla in Ashuganj, beside the Meghna River, sometime back. More land is available for acquisition by the government just beside this land if in case, after the installation of the compressor station, there would be a requirement for more land for the future straddle plant project. The country's North-South 30-inch mainline sales gas transmission & distribution pipeline runs from the Kailashtilla upazila, Golapganj, Sylhet to Ashuganj via Rashidpur & Brahmanbaria. Likewise, a 6-inch natural gas liquid pipeline also was installed side by side with 30-inch main gas line. The central point of those two (2) pipelines is at Ashuganj, where sales gas is being transmitted to the different gas distribution companies of Petrobangla & the condensate is received at RPGCL's condensate storage tanks. The sales gas & condensate pipelines were laid by GTCL (Gas Transmission Company Limited). GTCL collects wheeling charges from the transmission of the sales gas & natural gas liquids.

The sales gas & condensate from Chevron's gas fields are pumped to Ashuganj via the North-South pipe line for further transmission to the distribution companies.

At Ashuganj, the pressure of the sales gas, which is near about 1,000 psig, is being monitored and the condensate flow is metered by GTCL's sophisticated SCADA System. Inter-district road & river communications with the surrounding districts are excellent. Hence, this Feasibility Study for Setting Up a Straddle Plant for NGL Extraction and Fractionation at Ashuganj is carried out because of Ashuganj's strategic location & suitability.

A map showing the existing natural gas transmission & distribution system throughout Bangladesh & the Ashuganj North-South gas transmission schematic drawing are shown in **Annexure 1 & 2**.

3.1.3.6 2nd SPECIAL MENTION: TITAS GAS TRANSMISSION & DISTRIBUTION COMPANY LTD'S PIPELINE SYSTEM: THE POSSIBILITY OF SETTING UP ANOTHER STRADDLE PLANT ALONG THE TITAS MAINLINE TRANSMISSION SYSTEM WOULD BE A VERY ATTRACTIVE PROJECT ONCE A STRADDLE PLANT PROJECT IN ASHUGANJ WILL HAVE BEEN BUILT, INSTALLED, TESTED, COMMISSIONED & TURNED-OVER TO THE CLIENT-OWNERS.

A map showing Titas Gas Transmission & Distribution schematic drawing is shown in **Annexure 3**.

Titas Gas Transmission & Distribution Company Limited, {TGTDC} is a premier gas transmission, distribution & marketing company of the country. Being a gas transmission & distribution company, it is also the sales gas implementing agency for & on behalf of Petrobangla. TGTDC is responsible for gas distribution and marketing in greater Dhaka and greater Mymensingh. The company performs upgrading and expansion of all gas distribution networks in Dhaka and nearby districts.

Titas is getting gas mainly from Titas gas field, Bakhrabad gas field, Habiganj gas field & Meghna gas field. Titas operates its own 12 to 6-inches main transmission pipe lines. They distribute the gas to the various types of consumers like industrials, commercials & domestic customers.

Titas {TGTDC} is always trying its level best to serve the nation to ensure better utilization of the sales gas supplied to households, commercial establishments, industrial concerns & CNG stations. It is trying to take more supply through Ashuganj & its franchise areas. Titas {TGTDC} playing an important role to the country by giving large amount of revenue. As a whole, Titas {TGTDC} is the oldest and largest gas marketing company of Petrobangla. This company handles about 68% of the country's natural gas sales although there are other gas transmission & distribution companies in the country.

In the drawing found in Annexure-3, TGTDC pipeline network shows Brahmabaria – Demra transmission line, Narshingdi – Ghorasal transmission line, Ashuganj Power station line, Habiganj – Ashuganj – transmission line, Titas – Narshingdi transmission pipeline and the Narshingdi – Ghorasal – Joydevpur transmission pipeline. There is a possibility to tie in the existing Titas main pipeline to the North-South pipeline by installing a gas compressor system.

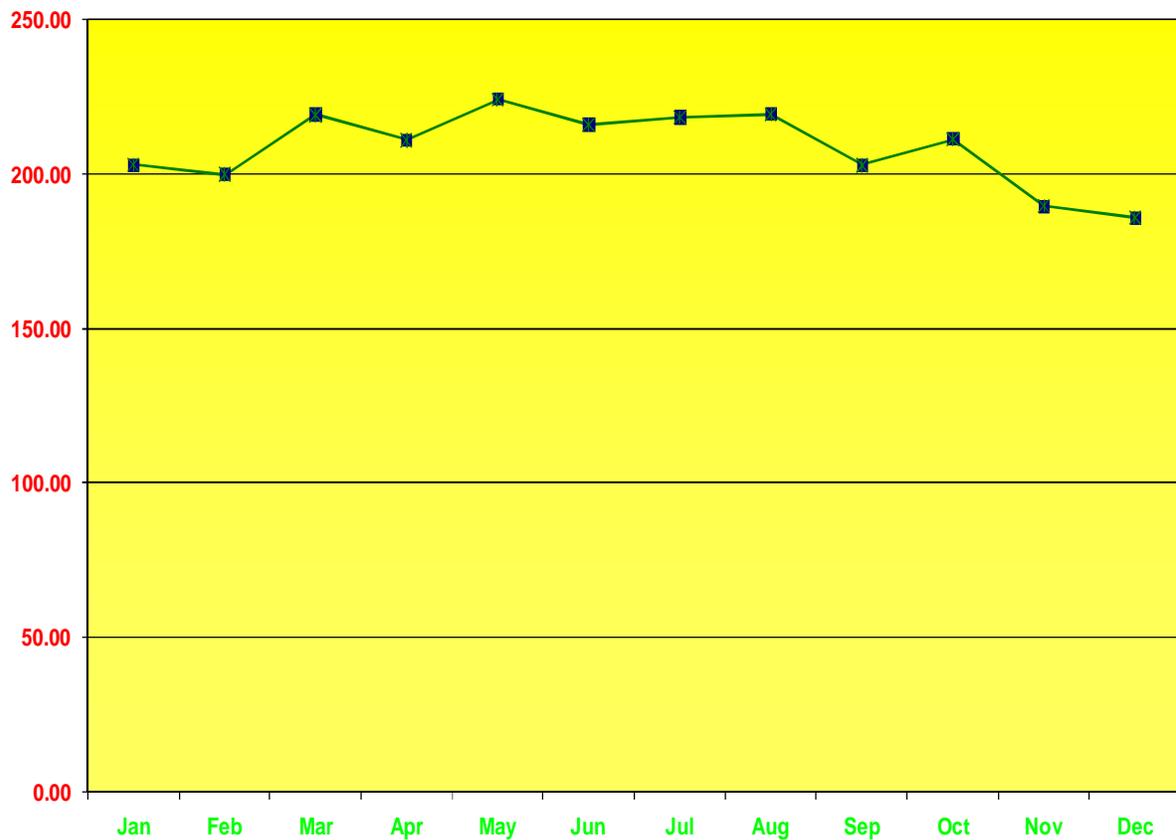
Titas {TGTDC} also plays an important role to the country's coffers by earning large amounts of revenue. As a whole, it is said that Titas {TGTDC} is the oldest and largest gas marketing company of Petrobangla. This company handles about 68% of the country's natural gas although there are also other gas transmission & distribution companies in the country such as GTCL, JGTDC, etc.

3.1.4 NGLs (NGL + Condensate) Production in All Currently Producing Gas Fields in Bangladesh

In Bangladesh, when there is gas, there will be **NGLs**. A line graph showing year 2009 NGLs (NGL + condensate) production in all currently producing gas fields is as follows:

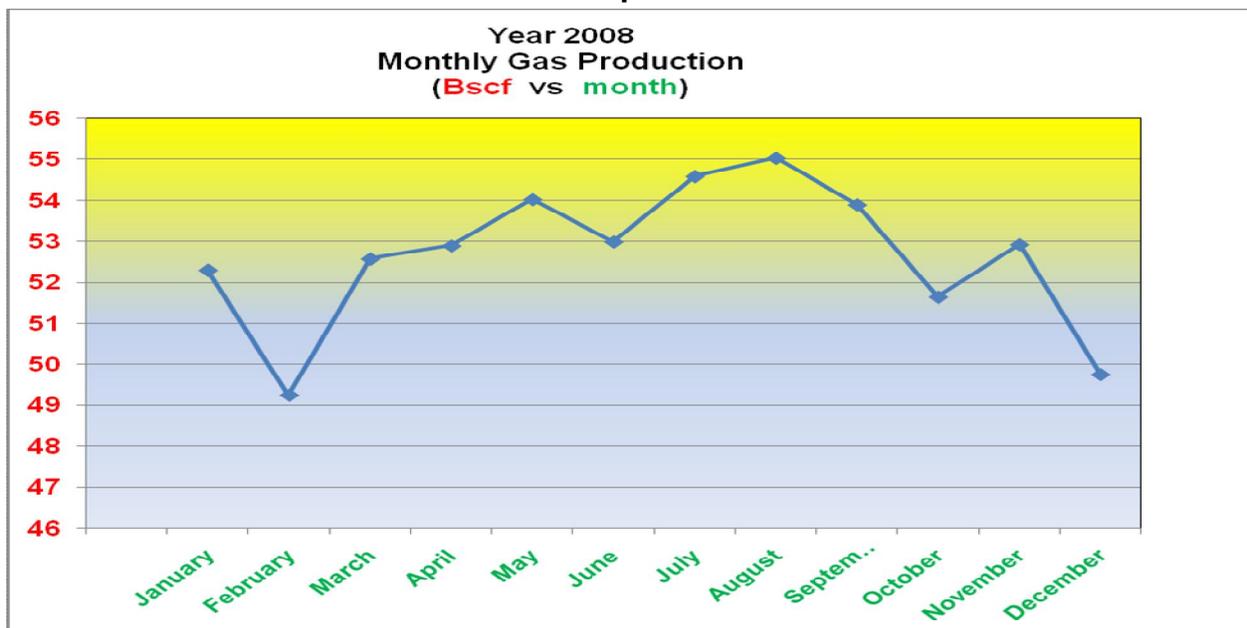
Graph 7

Year 2009
Monthly Condensate Production
(thousand bbls vs month)

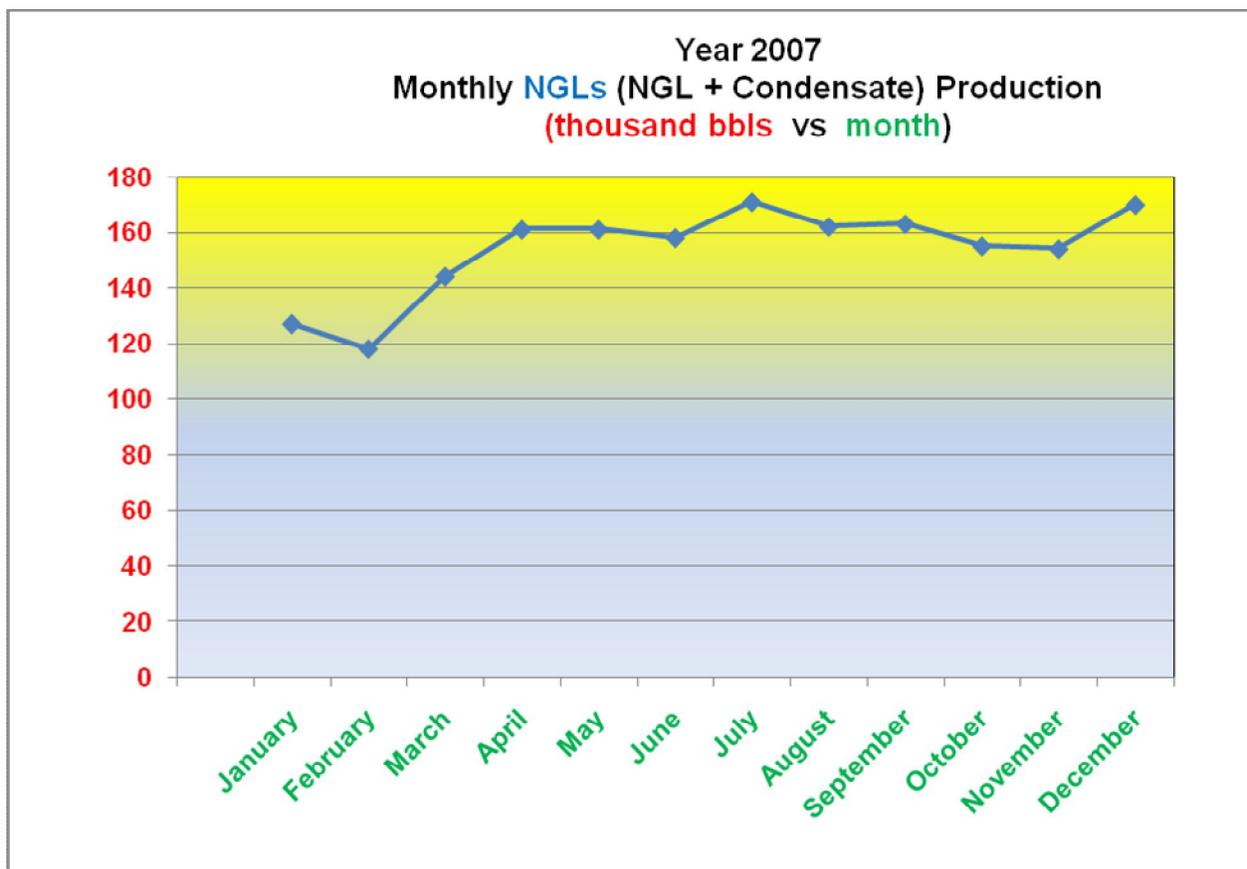


And for the previous four (4) years, 2005 – 2008, the monthly **NGLs** (NGL + Condensate) production graphs are as follows:

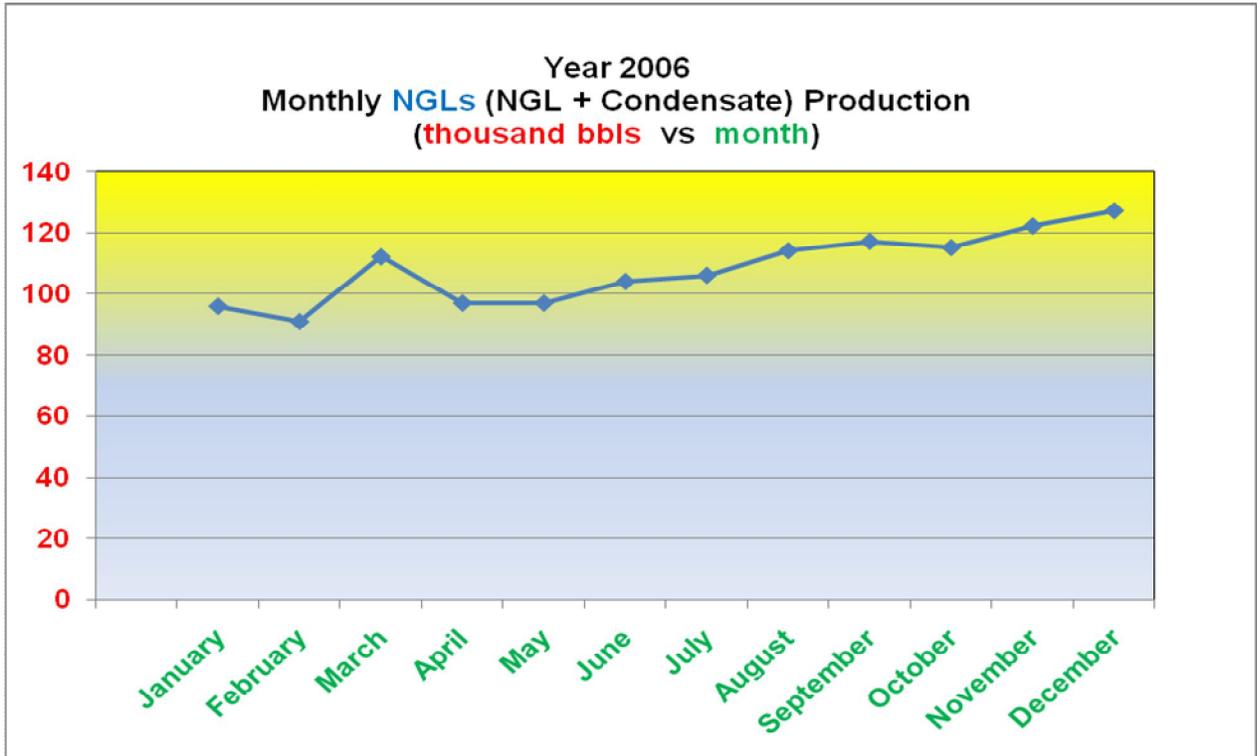
Graph 8



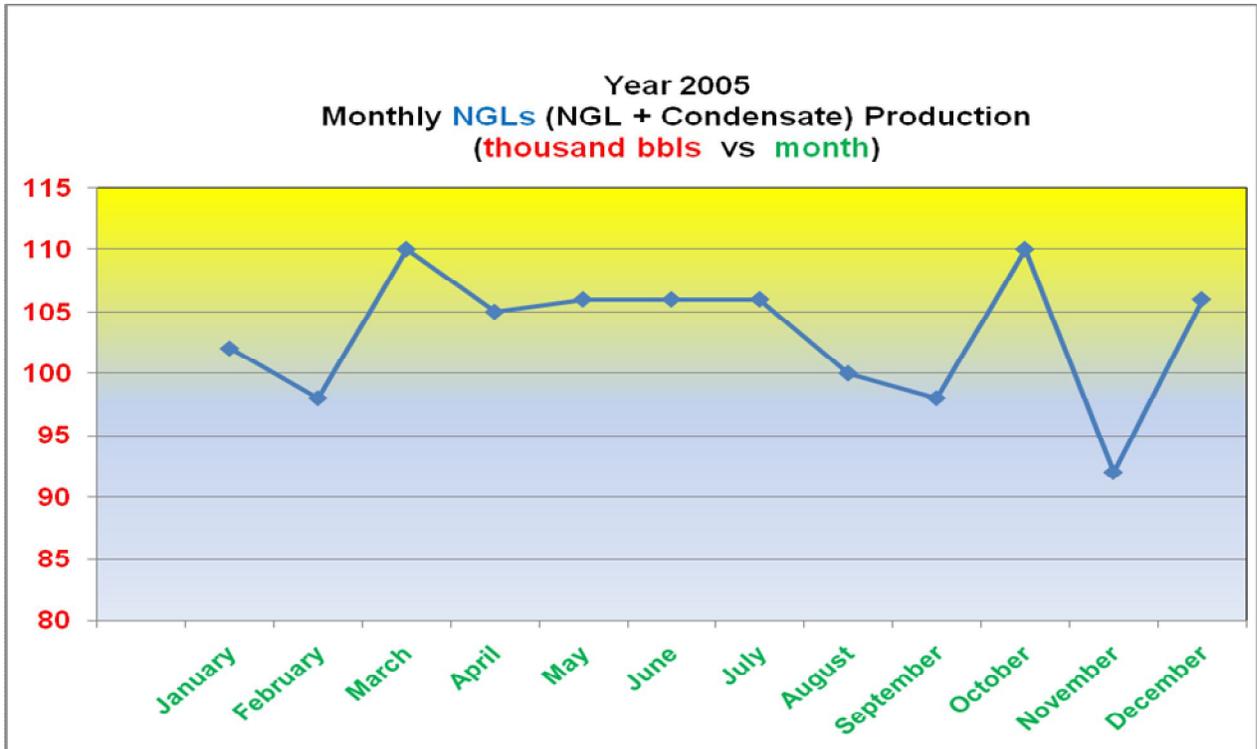
Graph 9



Graph 10

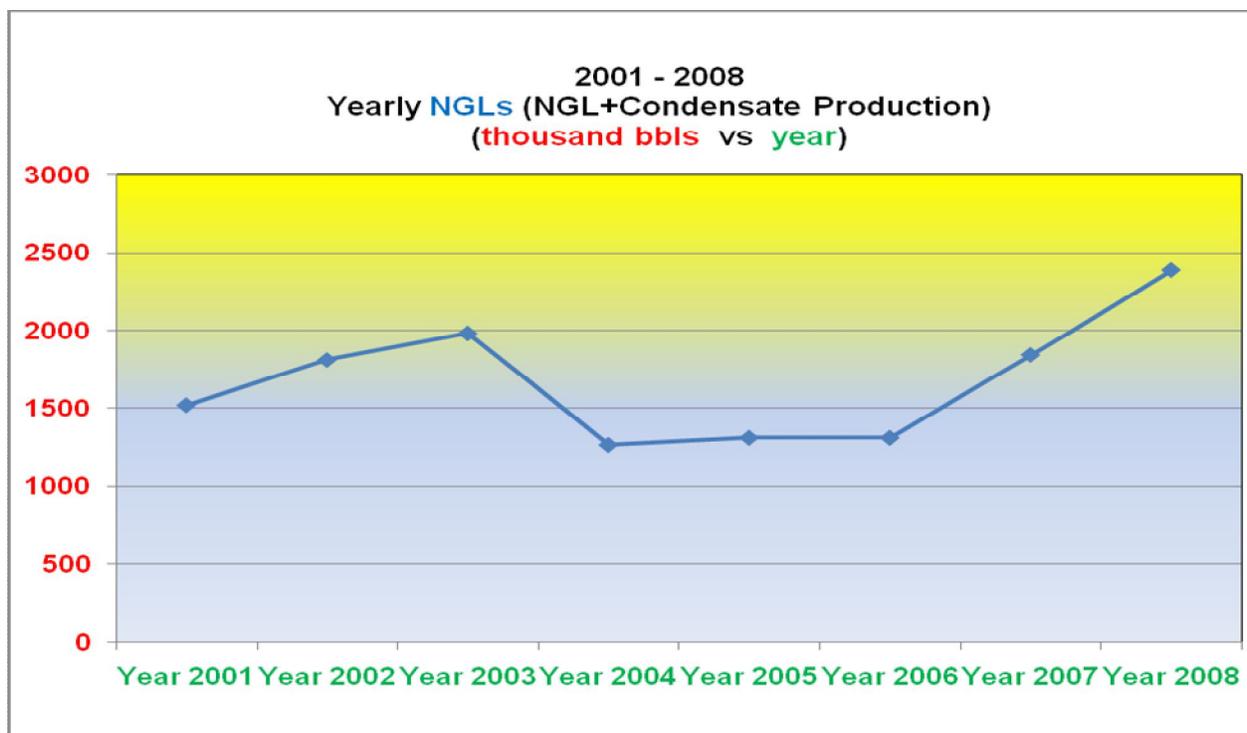


Graph 11



From 2001 – 2008, the **NGLs** (NGL+Condensate) yearly production is as follows:

Graph 12



Data collected & utilized in preparing graphs 1 - 12 are found in **Annexure 04 – 08**.

It is very clear from the above graph numbers 1 – 12 that as the gas production in Bangladesh goes up, so does the amount of **NGL's** that are recovered year after year. Most of the increases are heavy condensates (C₅+) though. This increasing **NGL's** production is an indication that something must be done to maximize their use. In fact, in the last eight (8) years (year 2001 to 2008) alone, the yearly condensate production went up from 1,519,000 bbls (15.19 Lakhs bbls) in year 2001 to 2,389,000 bbls (23.89 Lakhs bbls) in year 2008. **It has increased by almost fifty percent (50%).**

As of December 2009, the average daily production of **NGLs** (NGL's + Condensates) from all gas-producing fields amounts to **208,430 bbls per day (bpd)**.

In the field, the consumers of the **NGL's** include the RPGCL's Kailashtilla Fractionation plants in Golapganj, Sylhet which produces LPG, MS & HSD and SGFL's Condensate Fractionation plants in Kailashtilla-location-1 & Rashidpur, Sylhet which produces MS,

Kerosene & Diesel. Marketing of these products are done locally only. However, the ever increasing demand for compressed natural gas in the transport sector leaves behind the consumption of MS and HSD (diesel) since these two fuels are expensive as compared to CNG. After sometime, there will be a glut of gasoline and diesel in the storage tanks of MS & HSD (diesel) distribution depots and the production plants will start decreasing their output or shutting down process operations because of product marketing problems.

Those **NGL's** that are not processed (& sold) by these plants are sent to the RPGCL's condensate storage tanks located in Ashuganj via an existing 6" NGL pipeline. GTCL operates the 6" NGL pipeline while RPGCL operates the condensate storage tanks. From the storage tanks the condensate is loaded unto oil tankers at the RPGCL-operated loading jetty at Meghna river in Ashuganj itself. From there, the condensate goes to the Eastern Refinery as feedstock blend.

3.1.4 Current Reserves of Natural Gas in Bangladesh

From the very first natural gas well discovered in Sylhet, Bangladesh in 1955 till now, the country has produced gas continuously and increasingly.

Cumulative production until that year (2003) reached 5,313 Bscf (5.313 Tscf). The remaining reserves were then placed at 11,327 Bscf (11.327 Tscf).

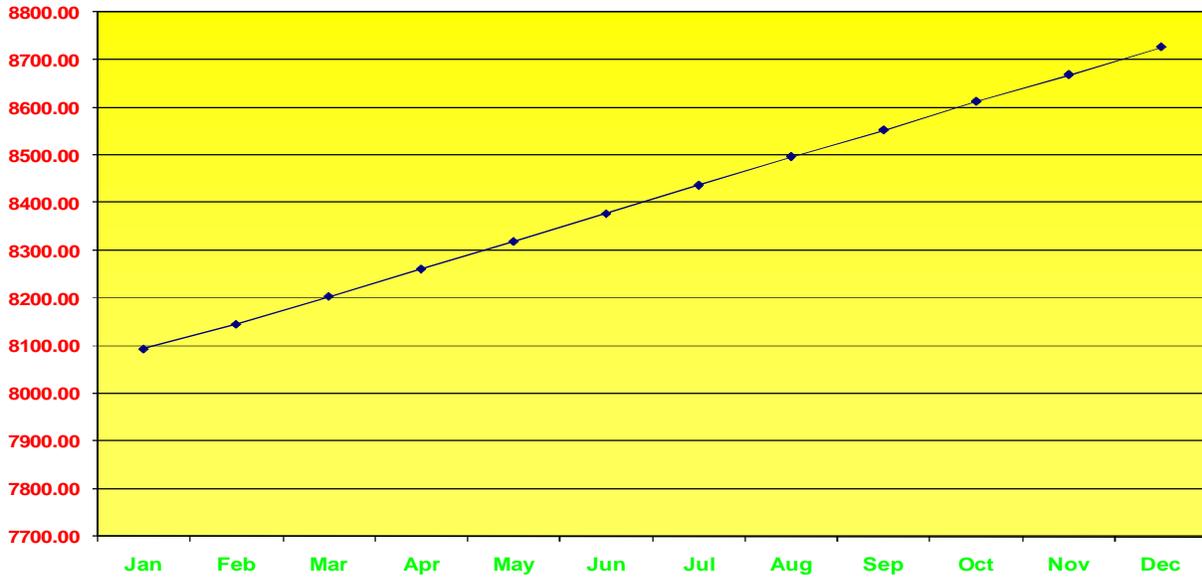
At that time the reserves of two (2) newly-discovered gas fields, namely Bangura & Srikail, which were discovered in 2004 were not yet included although preliminary studies indicate their reserves (2P) was in the range of 200 – 500 Bscf or 0.5 Tscf.

To have a good picture, let us see these trends in graphical form. Let us start with the cumulative gas production.

The graph of the cumulative natural gas production for this year alone (from January – December 2009) is as follows:

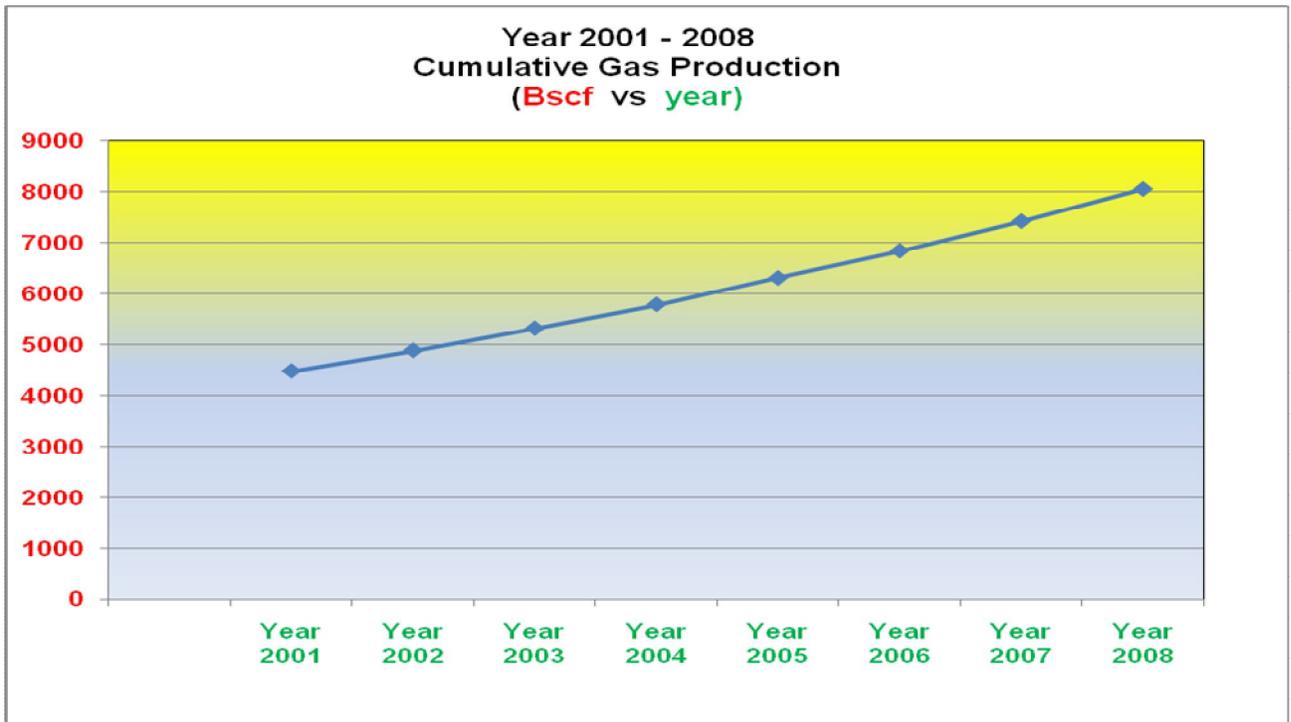
Graph 13

**Year 2009
Cumulative Monthly Gas Production
(Bscf vs Month)**



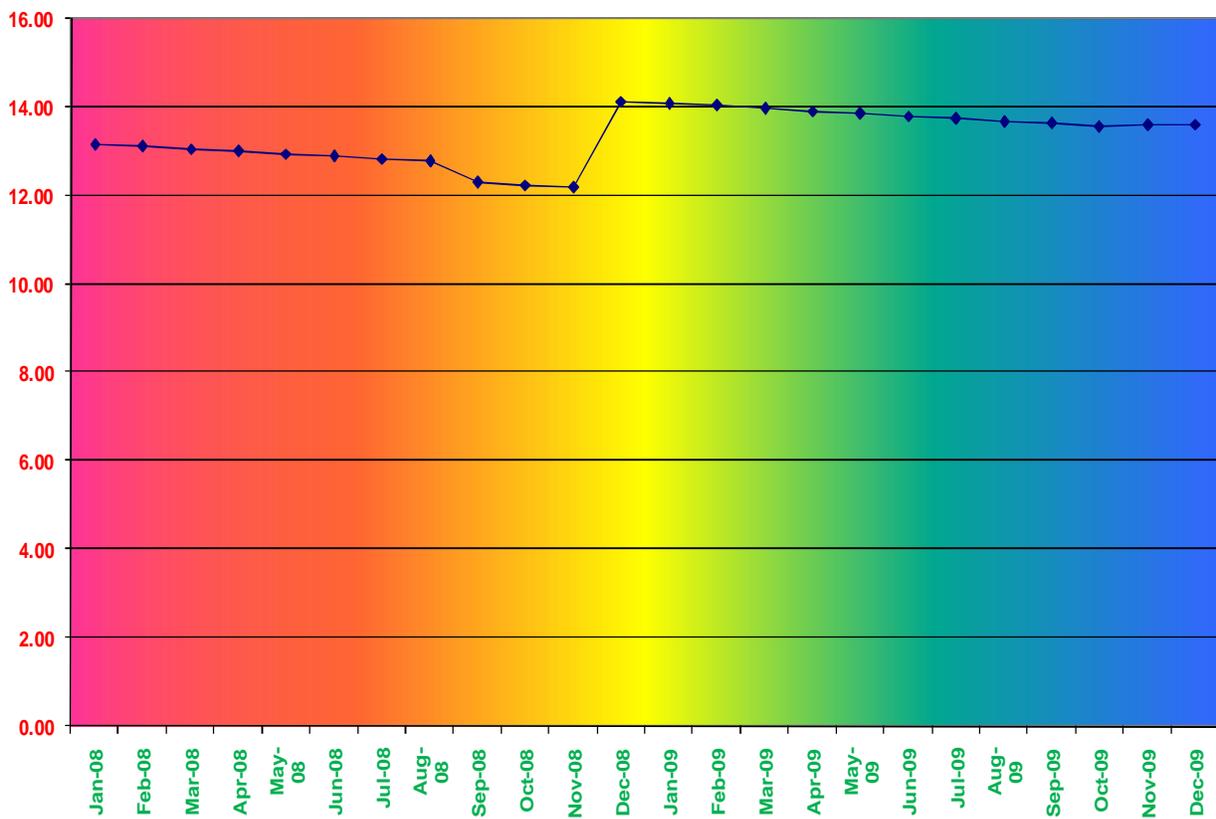
Furthermore, the graph of the cumulative natural gas production from year 2001 – 2008 is as follows:

Graph 14



At the end of December 2009, the cumulative gas production was 8.73 Tscf. Data used in generating the above graph nos 13 – 14 came from Hydrocarbon Unit & Petrobangla and can be viewed in Annexure 04 – 08. In the meantime, the graph of the natural gas reserves (2P) of Bangladesh for the year 2008 - 2009 is as follows:

Graph 15
Year 2008 - 2009
Gas Reserves 2P = (P1+P2)
(Tscf vs Month)



And the graph of the natural gas reserves (2P) of Bangladesh for the year 2005 - 2007 is as follows:

It is very clear from above **graph 15** that the gas reserves 2P (Proven + Provable) has of gone down. At present the following is the situation:

- Total Gas Reserves (GIIP) in Bangladesh is as follows:
P1 (Proven) = 20.84 Tcf ; P2 (Probable) = 7.62 Tcf
- Total (P1 + P2) = 28.47 Tcf
- Total Recoverable Gas Reserve is as follows:
P1 = 15.28 Tcf + P2 = 5.35 Tcf ; Total (P1 + P2) = 20.63 Tcf
- Cumulative Gas Production up to December 2009 is = 8.73 Tcf
- Remaining Gas Reserve is P1: 6.55 Tcf + P2: 5.35 Tcf = 11.90 Tcf
- Average daily Gas Production :1,873.52 mmscfd in December 2009
- Average monthly NGL and condensate production is 208,430 bbls for the month of December 2009
- Projected Gas production in 2020 : 2,525 mmscfd

Above figures included the increase of Bibiyana gas field's reserves based on the re-estimation of it s reserves by their Consultant Ryder-Scott. Document can be found in the next 2 pages.

3.1.5 Forecast Estimation of Natural Gas Production & Natural Gas Reserves in All Currently-Producing Gas Fields as well as the Most Likely Natural Gas Reserves & NGLs (NGL + Condensates) as a Result of Contemporaneous Exploration Both Offshore & Onshore

Please refer to the following **Annexure-09 Table 3.1: "Projection of Daily Gas Production"**

For the current year 2009 (June) - 2010 (June), the projected daily gas production shall reach a total of 2,002 mmscfd. Of this amount, 965 mmscfd will come from the NOC's (Petrobangla) while 1,037 mmscfd shall come from the IOC's-1.

Bibiwana gas field alone has the capacity to produce 650 – 700 mmscfd. However, they cannot push 700 mmscfd to the pipelines due to capacity constraints in the pipelines at current facilities. If the Muchai/Rashidpur compressor station will be installed, they can push this amount to the pipelines & supply more gas to the gas grid.

For the year 2010 (June) – 2011 (June), the projected daily gas production shall reach a total of 2,199 mmscfd. Of this amount, 1,144 mmscfd will come from the NOC's and 1,055 mmscfd will come from the IOC's-1.

For the year 2011 (June) – 2012 (June), the projected daily gas production shall reach a total of 2,355 mmscfd. Of this amount, 1,320 mmscfd will come from the NOC's and 1,035 mmscfd will come from the IOC's-1, zero from IOC's-2 & zero from IOC's-3.

For the year 2012 (June) – 2013 (June), the projected daily gas production shall reach a total of 2,530 mmscfd. Of this amount, 1,525 mmscfd will come from the NOC's, 855 mmscfd will come from the IOC's-1, 150 mmscfd will come from IOC's-2 & zero from IOC's-3.

For the year 2013 (June) – 2014 (June), the projected daily gas production shall reach a total of 2,650 mmscfd. Of this amount, 1,705 mmscfd will come from the NOC's, 795 mmscfd will come from the IOC's-1, 150 mmscfd will come from IOC's-2 & zero from IOC's-3.

For the year 2014 (June) – 2015 (June), the projected daily gas production shall reach a total of 2,605 mmscfd. Of this amount, 1,710 mmscfd will come from the NOC's, 745 mmscfd will come from the IOC's-1, 150 mmscfd from IOC's-2 & zero from IOC's-3.

For the year 2015 (June) – 2016 (June), the projected daily gas production shall reach a total of 2,660 mmscfd. Of this amount, 1,710 mmscfd will come from the NOC's, 700 mmscfd will come from the IOC's-1, 150 mmscfd will come from IOC's-2 & 100 mmscfd will come from IOC's-3.

For the year 2016 (June) – 2017 (June), the projected daily gas production shall reach a total of 2,725 mmscfd. Of this amount, 1,810 mscfd will come from the NOC's, 665

mmscfd will come from the IOC's-1, 150 mmscfd from IOC's-2 & 100 mmscfd will come from IOC's-3.

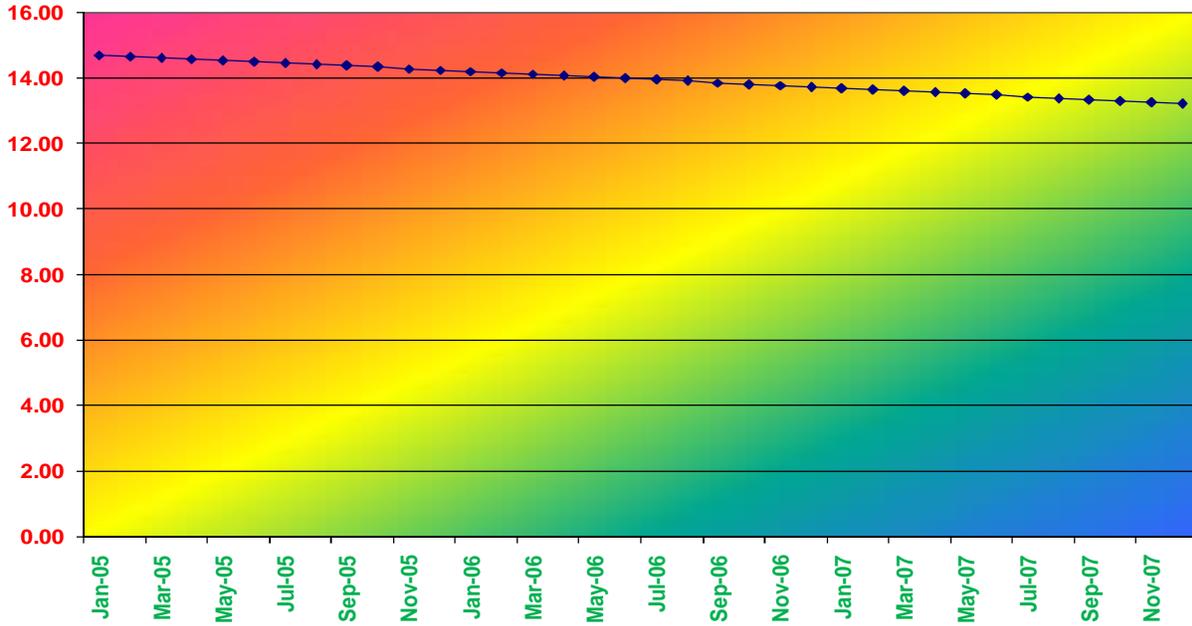
For the year 2017 (June) – 2018 (June), the projected daily gas production shall reach a total of 2,650 mmscfd. Of this amount, 575 mmscfd will come from IOC's-1, 150 mmscfd will come from the IOC's-2 & 100 mmscfd from IOC's-3.

For the year 2018 (June) – 2019 (June), the projected daily gas production shall reach a total of 2,580 mmscfd. Of this amount, 1,820 mmscfd will come from the NOC's and 510 mmscfd will come from the IOC's -1, 150 mmscfd from IOC's-2 & 100 mmscfd from IOC's.-3.

For the year 2019 (June) – 2020 (June), the projected daily gas production shall reach a total of 2,525 mmscfd. Of this amount, 1,820 mmscfd will come from the NOC's, 455 mmscfd will come from the IOC's-1, 150 mmscfd from IOC's-2 & 100 mmscfd from IOC's-3.

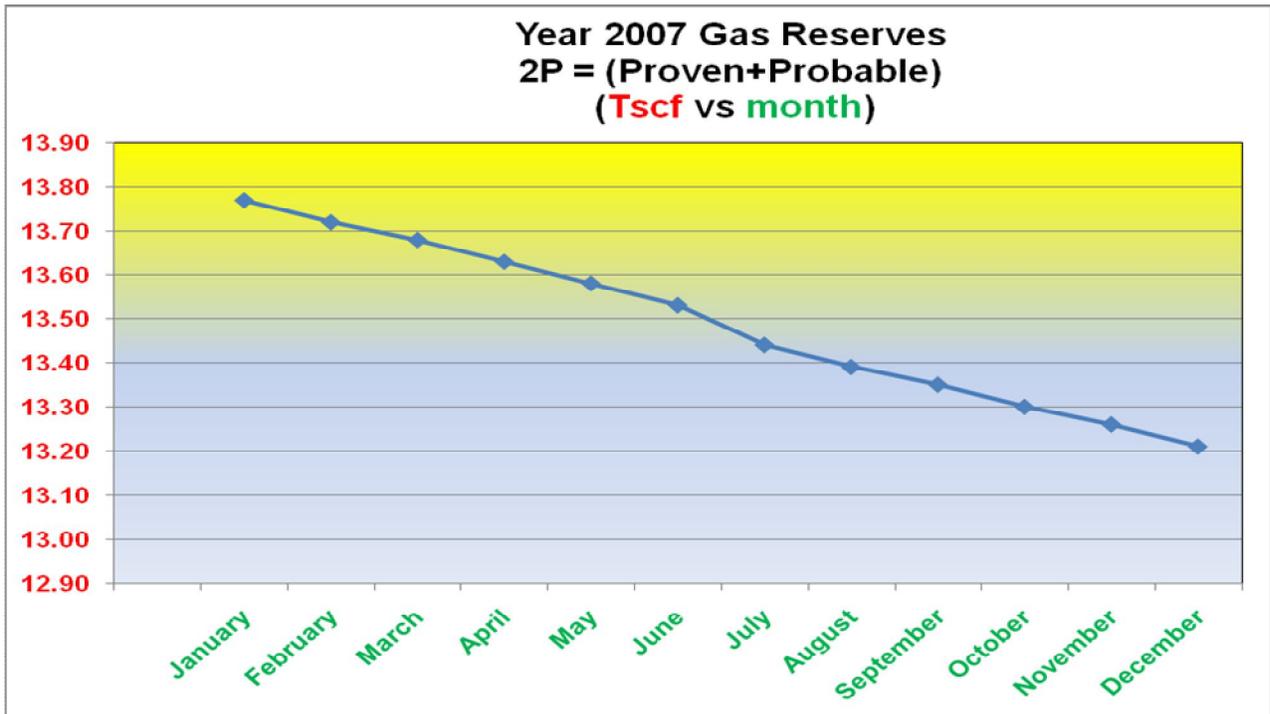
Graph 16

Year 2005 - 2007
Gas Reserves 2P = (P1+P2)
(Tscf vs Month)

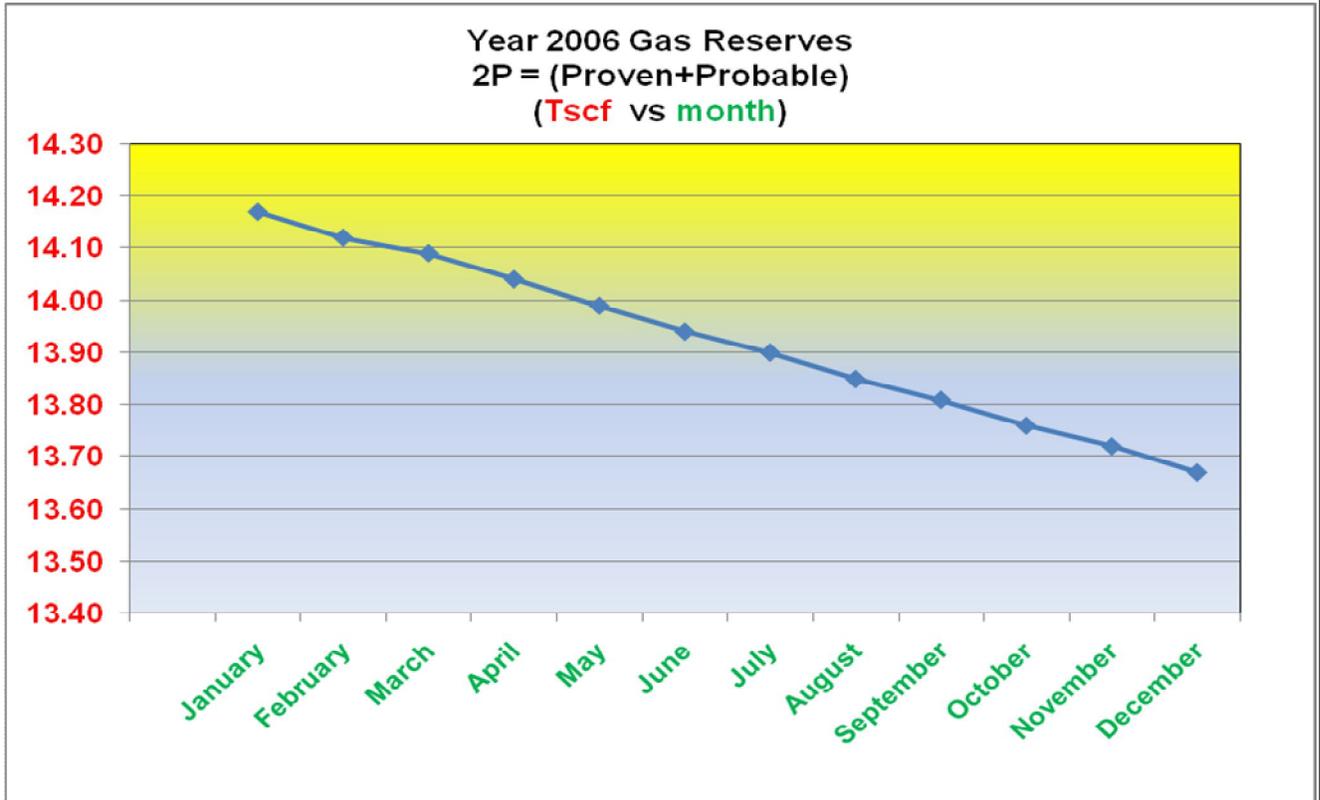


Graph 17

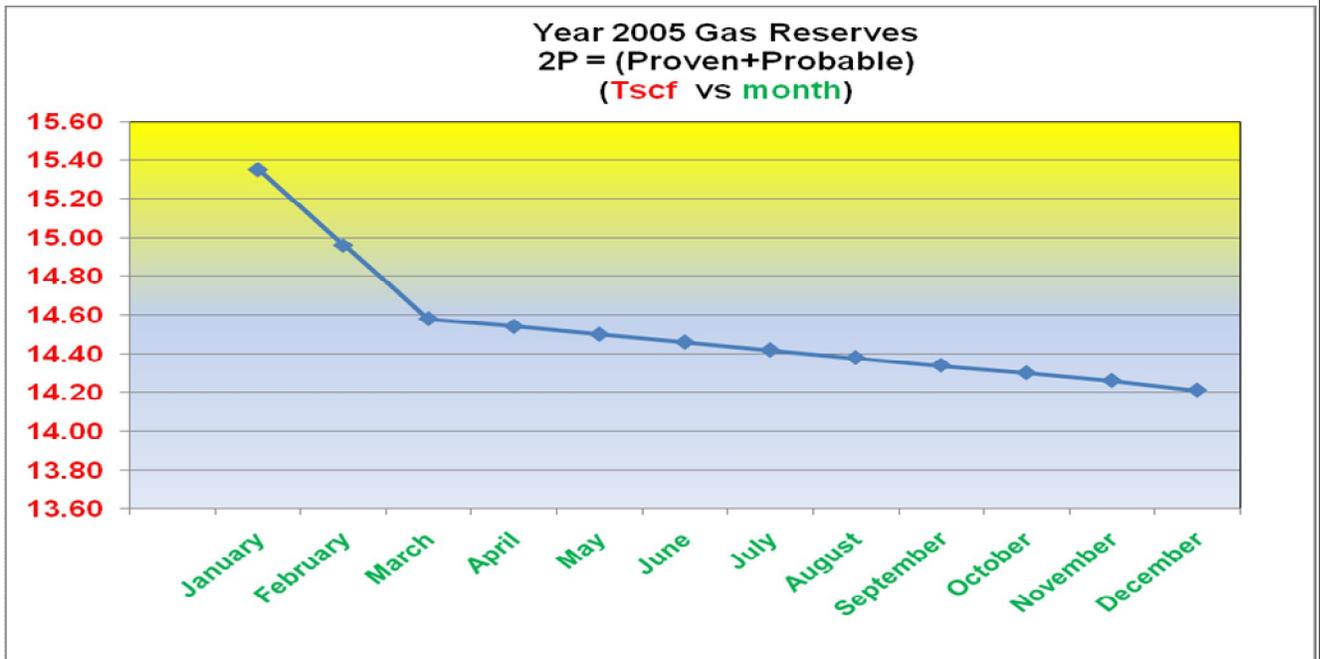
Year 2007 Gas Reserves
2P = (Proven+Probable)
(Tscf vs month)



Graph 18



Graph 19



The data used in generating the above graphs for the gas reserves are in **Annexure 04 - 08:**

3.2 Determine extractable amount of NGL (including ethane) towards preparation of a techno-economic model to determine the feasibility of setting up a straddle plant for NGL extraction including Fractionation which could process NGL from extraction plant.

After thoroughly studying all collected data and running several techno-economic model combinations via computer simulations, the Consultant has come with an optimized techno-economic model that fit this feasibility study.

The following is the step by step approach whereby a techno-economic model was assembled hereto:

Please refer to Annexure-10, Table 3.2: Projection of Daily Gas Condensate Year 2009 - 2020.

From the above-mentioned Annexure-10, Table 3.2, it was found that a steady local supply of condensate from the existing as well as the soon-to-be-discovered gas wells, is available if ever this project will be implemented. In the event that the future gas wells cannot supply the required condensate, there is always that option to import raw condensate from other countries such as Indonesia, Qatar, Myanmar, Iran, Iraq, Libya, Algeria, Russia, Azerbaijan, etc.

Furthermore, after studying & digesting all the collected field data during the site visits as well as data collected from the offices of Petrobangla & IOCs', **Annexure-11, Table-3.3: Gas Blend Analysis** was assembled & assumed as an appropriate gas blend model for this feasibility study. This is based on the fact that the gas analysis data collected from the 30-inch GTCL North-South Mainline Gas Transmission & Distribution Pipeline had very similar analytical figures. Please see **Annexure 12: GTCL 30-inch Mainline Gas Analysis** report.

From there, the following assumed techno-economic model parameters were made as per terms of reference (ToR) of this project:

3.2.1 TECHNO-ECONOMIC MODEL

3.2.1.1 (Assumed) High-Value Marketable End-Products, as of Year – End 2009:

To create a clear understanding regarding the possible high-value marketable products of the straddle plant complex, the following is a brief description of each product:

- a) Polyethylene & Polypropylene prills/pellets/granules**
Please see Annexure-13 – 36 and Annexure 83 - 87.
- b) Precipitation Naphtha**
Please see Annexure-37.
- c) Mineral Turpentine**
Please see Annexure-38.
- d) BTX Aromatics (Benzene, Toluene & Xylene): Used as solvents**
Please see Annexure-39 - 48.
- e) Octane Number Booster/Additive**
Please see Annexure-49.
- f) Cetane Number Booster/Additive**
Please see Annexure-50.
- g) Motor Spirits**
Please see Annexure-51-53.
- h) High Speed Diesel**
Please see Annexure- 54 - 57.
- i) Kerosene**
Please see Annexure-58 - 63.
- j) Liquefied Petroleum Gas**
Please see Annexure-64 - 69.
- k) Methanol**
Please see Annexure-70 - 76.

l) Formaldehyde

Please see Annexure-77 - 79.

m) Ammonia

Please see Annexure-80 - 82.

3.2.1.2 (Assumed) Raw Material Design Requirements:

Assumed Feed Gas:

1,300 mmscfd from North-South pipeline with the following assumed break-up:

350 mmscfd (minimum) from Chevron's Bibiyana gas field (More but sustainable will be better)

650 mmscfd (minimum) from BGFCL's Habiganj gas field

300 mmscfd (minimum) from SGFL's Rashidpur/Kailashtilla/Haripur/
Chevron's Jalalabad/Moulavibazar gas fields

Assumed Feed Condensate:

6,200 barrels per day (minimum) from Kailashtilla/Bibiyana/Moulavibazar/Rashidpur/
Sylhet(Haripur)/Beanibazar/ Bangura/BakharBabad/Meghna/Feni/Chattak/New
IOCs 2+3 gas field Discoveries mixed NGLs

Assumed Required Raw Feed Condensate-Gas Ratio = 4.75

3.2.1. (Assumed) Other Conditions At This Point in Time

1 USD Dollar = 70 Taka

Crude Oil Price = 65 – 70 US Dollar Per Barrel

3.3 Prepare conceptual design, cost estimates, economic analyses and opportunity cost comparisons for Potential uses of NGL for Petrochemical i.e. NGL mix feed ethylene cracker with polyethylene and polypropylene plants, olefins plants, etc.

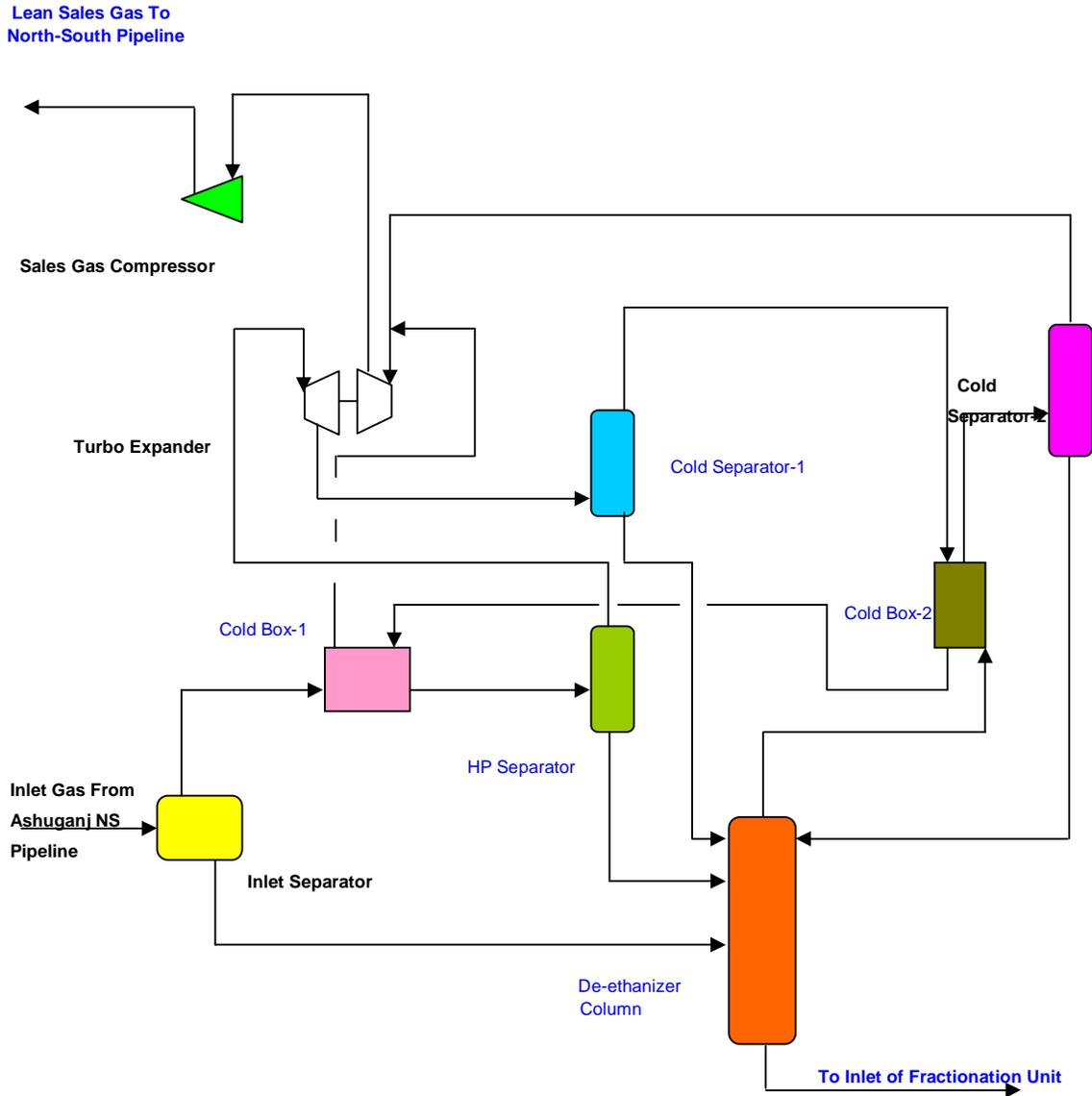
Twenty (20) years ago (1989), a preliminary report for “LPG Study Update” was prepared & submitted by RTM Engineering Ltd., Calgary, Alberta, Canada to CIDA (Canadian International Development Authority), Bangladesh. This preliminary report dealt with natural gas demand, production forecast, reserves, gas analyses, existing & approved LPG systems, LPG extraction & fractionation, LPG marketing system, market analysis, economic analysis & environmental & sociological impacts at that time.

Later, in 2002, a final report on the “Strategic Gas Utilization Study for the Peoples Republic of Bangladesh” was prepared & submitted by S.H. Lucas & Associates, Pasadena, California, U.S.A. to Petrobangla. This final report dealt with the potential uses of natural gas liquids (NGLs), Compressed Natural Gas (CNG) for vehicles use, screening additional ammonia/urea production, feasibility of liquefied natural gas (LNG) for export, supply & strategy for the electric industry & strategy for resolving the economic issues.

In year 2006, a final report on “Preparation and Development of Gas Sector Master Plan & Strategy for Bangladesh” was prepared & submitted by Wood Mackenzie Ltd., Edinburgh, United Kingdom to Petrobangla. This final report dealt with regional gas demand analysis, regional supply analysis, and approach for development of the gas strategy and gas sector master plan and plan for subsequent work.

In preparing this feasibility, various strategic approaches were studied. Several patent owners of petrochemical processes were contacted for their assessments and several plant and machinery equipment manufacturers & vendor’s budgetary quotation requests were made. Companies such as Shell Petrochemicals Division, European Petrochemical Company, Formosa Plastics Group in Taiwan & Jubail Petrochemical Company (Petrokemya), Kingdom of Saudi Arabia were sources of figures & data to give some light to this project.

3.3.1 Conceptual Process Flow Diagram of Straddle Plant NGL Extraction Unit



In Bangladesh, gas companies such as BGFCL, SGFL, Chevron, etc., process their raw gas in their respective field process plants and their respective sales gases (some send part of their total production) are sent to the 30-inch mainline transmission pipeline at Ashuganj. Figure 3.3.1 above, shows the conceptual process flow diagram of an NGL Extraction Plant using the deep-cut molecular sieve turbo expander (DC-MSTE) type

technology. The plant shall be designed to extract **NGL's** left in the gas that has not been recovered by the gas fields' processing plants.

In the above flow diagram, gas from the 30-inch North-South Ashuganj mainline distribution pipeline is piped to the inlet knock-out separator of the deep-cut MSTE process plant. The liquids that are recovered from the inlet separator go to the de-ethanizer column to separate the ethane from the heavier fractions. On the other hand, the gas from the inlet separator goes to cold box-1 where it is cooled. The condensed liquids from cold box-1 go to high pressure separator-1, while the gas from cold box-1 goes to the compressor side of the turbo expander, then to the residue sales gas compressors and then sent back to the 30-inch Ashuganj North-South mainline gas transmission pipeline. The liquids condensed from cold box-1 go to the high-pressure separator whereby the liquids are separated from the gas. The liquids from the high-pressure separator go to the de-ethanizer column for separation and the gas goes to the expander side where it undergoes expansion at very high velocities. The expanded gas goes to cold separator-1 for separation of the liquids from the gas. The liquids from cold box-1 then go to the de-ethanizer column for separation of ethane while the gas goes to cold box-2 for further cooling. The liquids separated from cold box-2 go back to cold box-1 while the gas goes to cold separator-2 for separation of the gas from the liquids. The liquids from cold separator-2 go to the de-ethanizer column while the gas blends with the gas from cold box-1 and goes to the compressor side of the turbo expander.

Meantime, the de-ethanizer overheads go to cold box-2 while the bottoms go to the fractionation plant inlet.

3.3.2 Conceptual Process Flow Diagram of Straddle Plant NGL Fractionation Unit

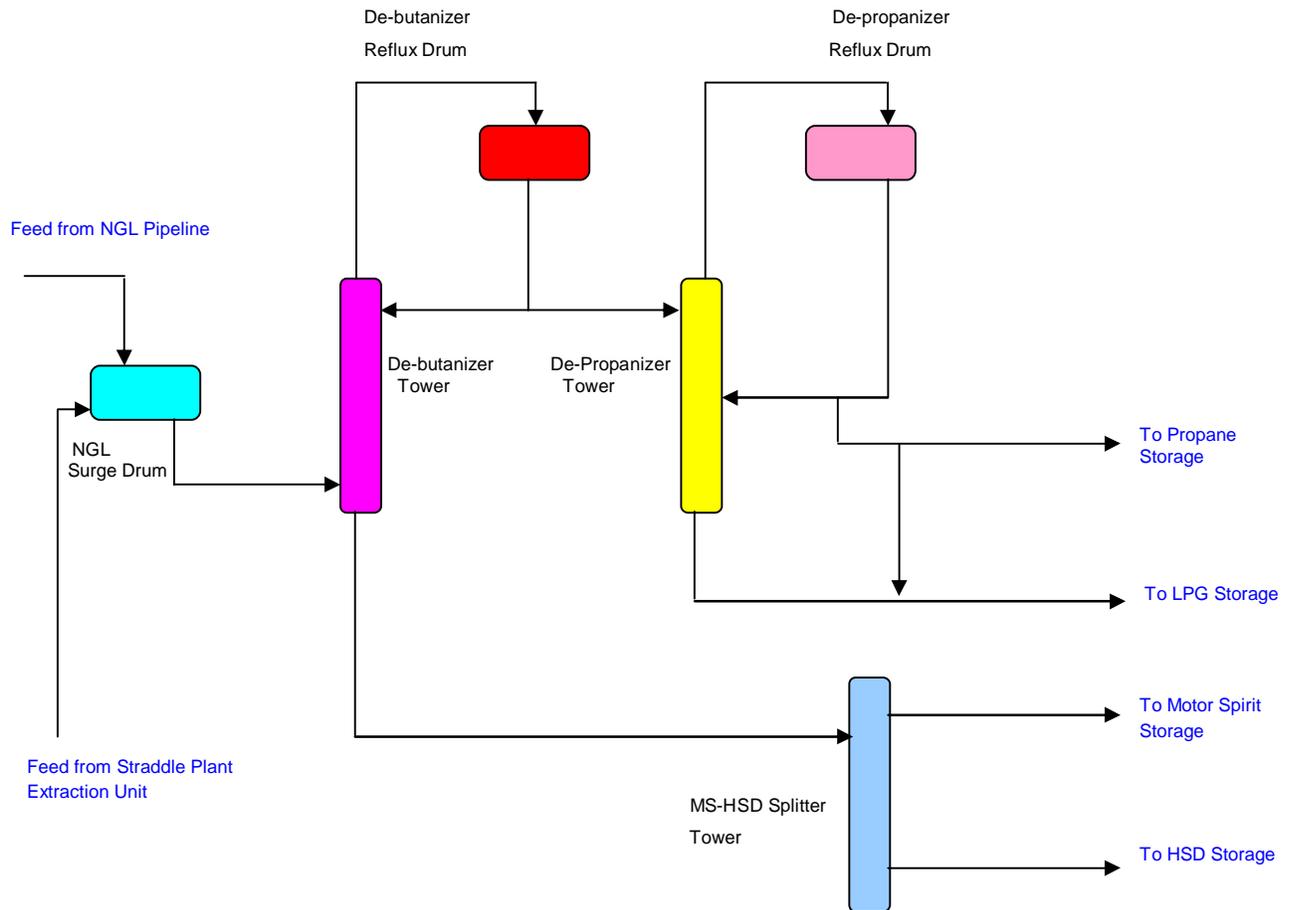


Figure 3.3.2 above shows the conceptual process flow diagram of the straddle plant's NGL fractionation unit. NGL from the straddle plant's extraction unit as well as **NGLs** from the pipeline are received at the inlet of the plant and enter the NGL surge drum, which permits the liquids to stabilize for the operation of the fractionation unit. The mixed NGLs enter the de-butanizer tower where heat is used to separate the butanes from the heavier fractions. The overheads from the de-butanizer column go to the overhead reflux drum. A recycle line sends a portion of the butanes back to the de-butanizer tower while the rest goes to the de-propanizer tower. The bottoms from the de-butanizer tower are then sent to the splitter tower for

fractionation into motor spirit and HSD. The overheads of the de-propanizer tower go to the de-propanizer reflux drum. One portion of the propane in the reflux drum is recycled back to the de-propanizer column, another portion is blended with LPG from the bottoms of the de-propanizer tower, while the remaining propane is sent to the propane storage tank.

The bottoms of the de-propanizer tower are blended with the propane to produce an LPG mixture. In general, LPG is usually a 50 / 50 blend mix of propane and butane.

Moreover, depending on the feed stock and plant operations, MS & HSD may be blended with octane booster additive and cetane booster additive respectively to give higher ratings to the motor spirit and HSD, hence producing higher value products to meet the stringent requirements thereof.

3.3.3 Conceptual Process Flow Diagram for Ethane Recovery

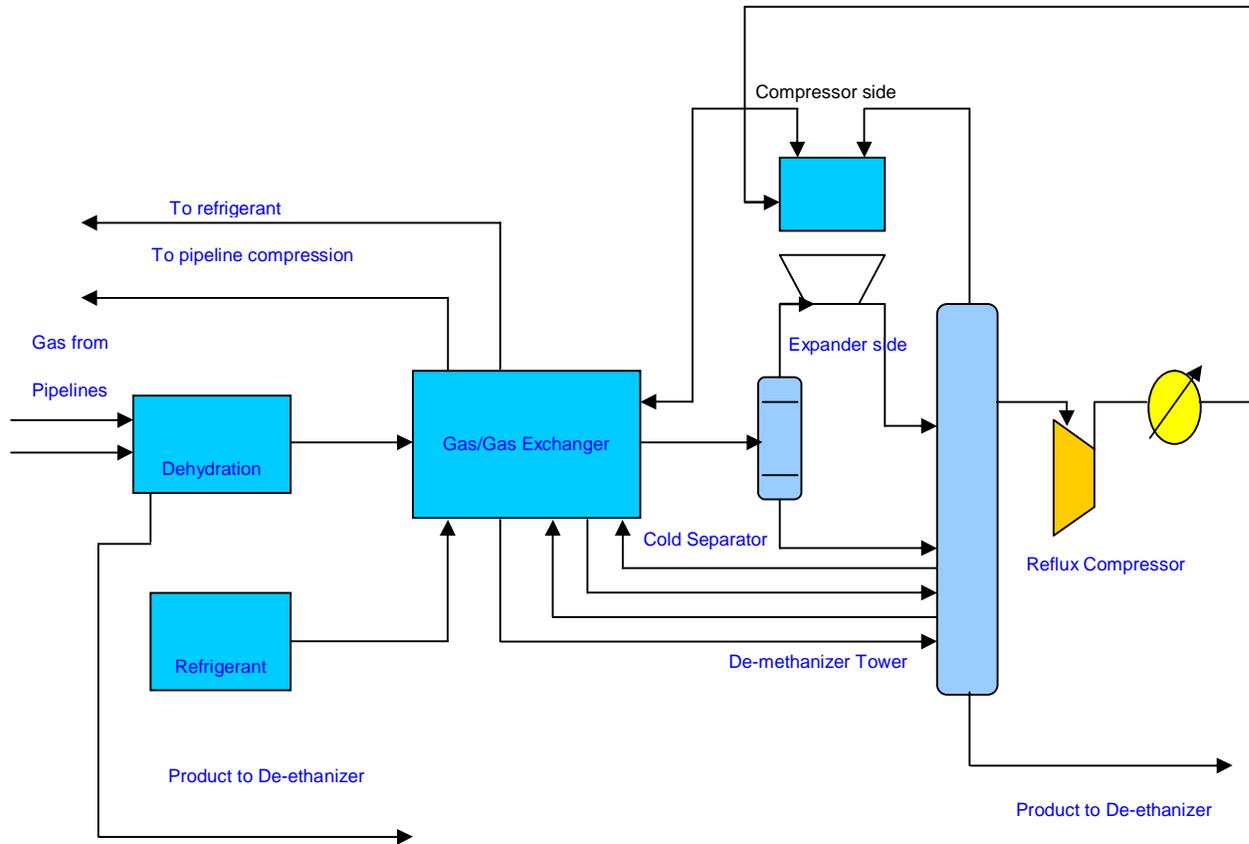


Figure 3.3.3 above shows a separate conceptual process flow diagram designed just for ethane recovery. Sales gas from the gas fields, i.e., BGFCL, SGFL, Chevron, etc., sales gas are received in the above-mentioned plant through a meter regulating station before it is being processed. As there are several processes available to recover ethane & remaining light NGLs which are still available in the gas, the selection depends on the yields required. Above is a typical process layout but is by no means the final design configuration that could be used in Ashuganj. An MSTE type of gas processing is used here to maximize the recovery of ethane. Inlet feed gas passes through mole sieves where it is first dehydrated. Then it is primarily cooled by a refrigerant and then cooled further against the residual gas coming from the compressor side of the MSTE. The recovered heat is used for heating the de-methanizer column.

The chilled gas is then passed through the cold separator where condensate liquid is separated, flashed & then fed to the middle section of the de-ethanizer column. A J-T valve is normally installed in parallel with the expander unit. The J-T valve then can used to handle excess gas flow beyond the design of the expander or can be used for the full flow if the expander unit is not in service. In this process, the ethane recovery is about 80%. Higher quantities of ethane can be obtained with additional refrigerant reflux compression. The additional reflux capability provides more refrigeration to the system and allows a higher ethane recovery. The ethane and the other liquids recovered from the gas in the de-methanizer unit are then passed through the de-ethanizer tower, where the ethane component is separated from the gas stream for transmission to the ethylene plant. The bottoms from the de-ethanizer tower are then blended in a surge drum with the **NGLs** coming from the pipeline system before going to the de-butanizer, de-propanizer and splitter towers.

Depending on the stream composition and the type of process selected, the location of the de-propanizer and the de-butanizer towers in the process configuration can vary.

3.3.4 Conceptual Process Flow Diagram for High LPG Recovery with Input Streams

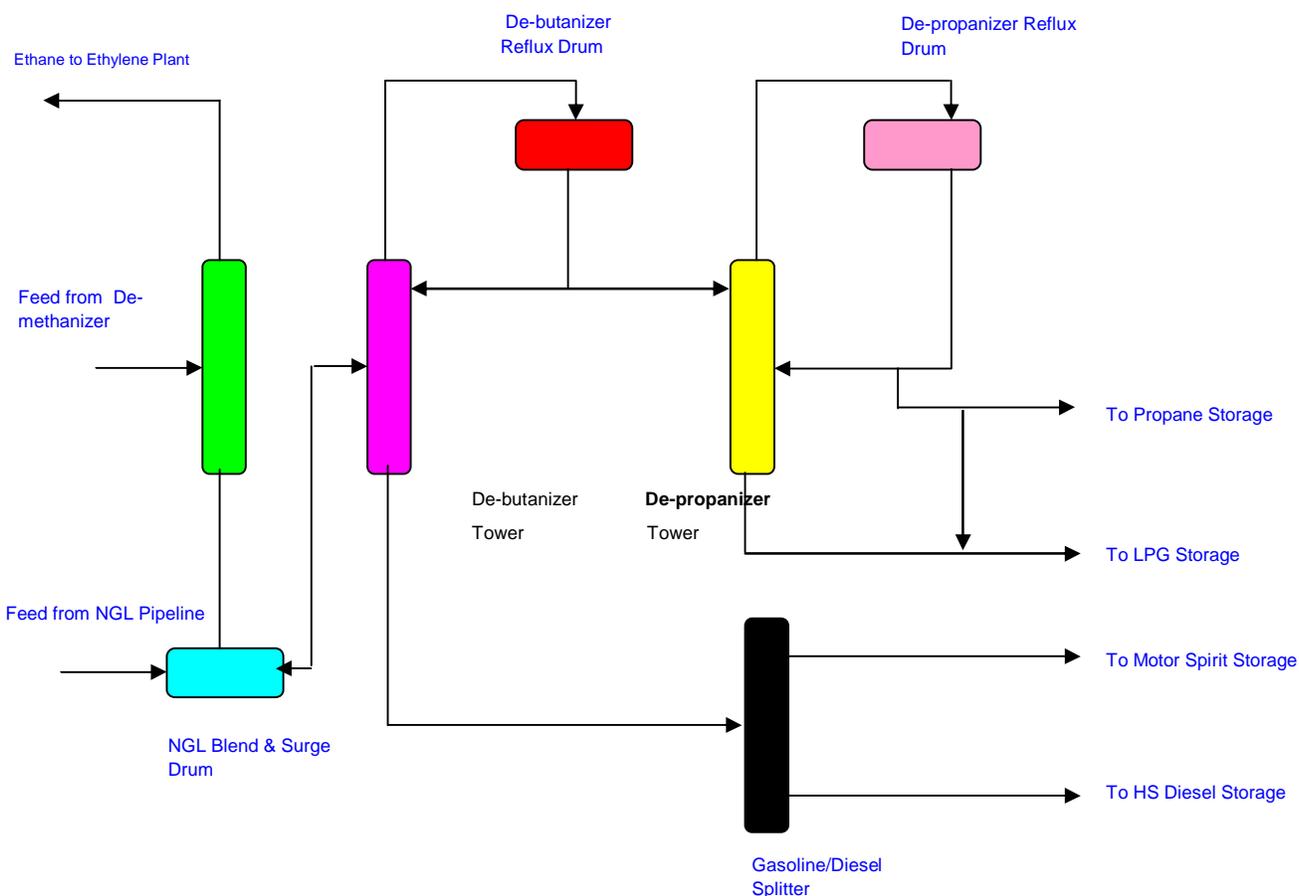


Figure 3.3.4 above shows a conceptual process flow diagram for high LPG recovery with input streams shown in Annexure 11: Table 3.3: Gas Blend Analysis. In the above diagram, **NGLs** from the pipeline are received in the NGL blend & surge drum whereby the bottoms also of the de-methanizer column blends with the incoming feed from the pipelines before it is passed through the de-butanizer, de-propanizer and splitter towers.

The bottoms from the de-ethanizer tower are blended in the de-ethanizer tower and also blended in the surge drum with NGLs coming from the sales gas pipeline system before passing to the de-butanizer, de-propanizer and splitter towers. Depending on the stream composition and the type of process selected, the location of the de-propanizer and the de-butanizer towers in the process configuration can be varied. This configuration is suitable for the gas-liquids stream found in Bangladesh.

A typical self-explanatory conceptual process flow schematic diagram for an ethane/propane cracking system is as follows:

3.3.5 Conceptual Process Flow Schematic Diagram of an Ethane/Propane Hydro-Catalytic Cracking Plant for the Ashuganj Straddle Plant Complex

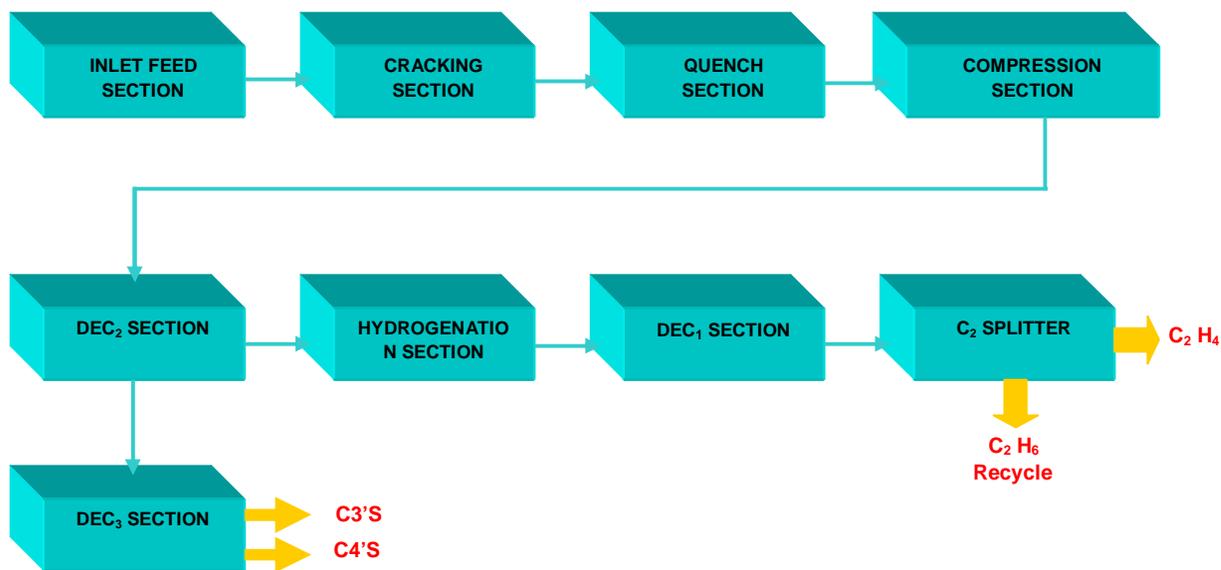


Figure 3.3.5 above shows an ethane/propane hydro-catalytic cracking process flow schematic diagram. Inlet feed stocks are sent to the “Inlet Feed Section”, where the raw materials are prepared for the cracking process. Then it enters the cracker unit where heat and catalysts are used to start the cracking process. Then it is followed by quenching, then compression, hydrogenation, splitting, recycle and product separation.

NAPHTHA CRACKER

A naphtha cracker plant is a plant that uses a cracking process to produce olefins such as ethylene, propylene and crackates. The primary feed for the naphtha cracker plant is naphtha which will be thermally cracked to produce polymer grade ethylene and propylene, which will then undergo further processing. By-products produced during naphtha cracker processing with down stream processing facilities will produce ethylene, propylene, butadiene, etc., aromatic complexes for the production of benzene, toluene & xylene.

The fluidized catalytic cracker plant consists of catalyst section and a fractionating section that work together as an integral processing plant. In broad terms, naphtha is a flammable liquid. It is used in the petrochemical industry for producing olefins in steam crackers and chemical industries for solvent application. Naphtha is volatile, flammable and has a specific gravity of 0.7.

EXAMPLE OF A NAPHTHA REFINERY & CRACKER PLANT EQUIPMENT



3.4 Recommend other alternate use of NGL (including aromatics, methanol and derivatives) which may be economically competitive as well as attractive.

Other alternative uses of **NGLs** include the production of the following: kerosene, precipitation Naphtha, mineral turpentine (MTT), BTX Aromatics (benzene, toluene, xylene), methanol, formaldehyde/formalin & ammonia. All of these products have been included in the grand conceptual schematic diagram found in **Annexure – 88**. Description of each marketable product has been given in **Annexure 13 – 87**.

3.5 Recommend the best strategic use of the NGL components based on opportunity cost comparison.

Please see Annexure-88.

For the Straddle plant complex at Ashuganj, use of **NGL's** based on opportunity cost comparison would be as follows:

- (a) The best strategic recommended use of the C₅ plus NGL components will be to set up a straddle plant complex at Ashuganj to extract mixed NGLs from the BGFCL, SGFL and Chevron transmission lines where they intersect at Ashuganj point using deep cut MSTE plant for the extraction of **NGLs**.
- (b) Recover propanes and butanes in the field-stripping operation and send them, along with the condensates, to the first fractionation unit of the straddle plant complex.
- (c) Within the same complex the **NGLs** will be fractionated into ethane, propane, LPG, MS, HSD. Bulk LPG, MS and HSD can be sold locally.
- (d) Whenever higher quality specifications are required for the MS and HSD, Octane number booster and cetane number booster will be blended with the required quantity of additives so that the octane and cetane number booster will increase respectively, before they will be marketed to make them more competitive.
- (e) From the first fractionation tower, a sustainable quantity of naphtha will be produced. A Naphtha cracker plant is recommended, whose capacity shall be based on the quantity of the naphtha feed. Naphtha cracker is a plant that uses a cracking process to produce ethylene, propylene & other crackers double-bonded polymers from naphtha. There are several types of naphtha cracker depending on primary feed for naphtha, which will be thermally cracked to produce polymer grade ethylene and propylene, which will then undergo processing. Olefins are by-products produced during naphtha cracker processing. Naphtha with down stream processing to produce ethylene, propylene, methanol, formaldehyde etc. Aromatic complexes to produces benzene, toluene & xylene.

The fluid cracker consists of catalyst section and a fractionating section that together as an integral processing unit. In broad term Naphtha is a flammable liquid. Naphtha also used in petrochemical industry for producing olefins in steam crackers and chemical industries for solvent application . Naphtha is volatile, flammable and a specific gravity of around 0.7.

A number of different liquid mixtures of hydrocarbons, i.e. distillation products from cracked naphtha are usually volatile, flammable & has a specific gravity of about 0.7. From the straddle plant fractionation unit, the produced naphtha goes to the naphtha cracker and from there to the second fractionation plant to split some more multiple products, like MS, HSD, MTT and Kerosene. From the second fractionation tower, the cracked products passes to the production plant of the aromatic products like Benzene, Toluene & Xylene. The second fractionation unit will also produce intermediate product and feed stocks can be obtained to manufacture octane booster and cetane booster additives in their respective plants.

- (f) It is recommended to install an Olefin plant to produce feed stocks for the ethylene plant and a polyethylene plant based on ethane and propane feed stocks. The olefin plant shall produce feed stocks such that a 50% ethylene and 50% propylene ratio will be obtained to produce 50%:50% polyethylene and polypropylene products. These two products are highly marketable, locally as well as exportable. This way, a straddle plant complex having petrochemical products at Ashuganj will be much more profitable and highly feasible.

- (g) In view of the huge amount of capital expenditure required, it is recommended that should this feasibility study be made the basis for the implementation of EPC for a straddle plant complex for the extraction, fractionation, petrochemical production & marketing, a module-by-module implementation be carried out. That means for Module-1: Consist of NGL Extraction, Fractionation, Polyethylene Plant. Module-2 shall consist of the **NGLs** Extraction Plant, Fractionation Plant, Polyethylene Plant, Polypropylene Plant, Naphtha stripper, Kerosene stripper, Precipitation Naphtha stripper, Mineral Turpentine stripper, Octane Booster Plant, Cetane Booster Plant & LPG Bulk & Bottling Plants, MS/HSD loading areas & Storage/Production Tanks. It can function on its own.

Module-II shall consist of a Catalytic Naphtha Cracker Plant, a second Fractionation Plant for the Crackates, BTX (Benzene/Toluene/Xylene) Plant, Ammonia Plant, Methanol Plant, Formaldehyde/Formalin Plant, MS/HSD loading areas & Storage/Production Tanks

- (h) The grand conceptual schematic diagram of the above recommendations can be found in **Annexure – 88**.

- (i) The design life of the plant is 25 years; however, actual life of plant would be within the range of 30 to 40 years.
- (j) A financial analysis for the feasibility study for setting up a Straddle plant for NGL extraction & fractionation plant & petrochemical plant complex at Ashuganj containing the potential uses of **NGLs** are found in **Annexure 89 - 149**. The overall IRR is **28%**.

Assuming the price of ethane extracted by the straddle plant is charged as shrinkage, and the capital costs are within the range of accuracy estimated by us, the project exceeds the IRR threshold of 14% and therefore considered feasible.

3.6 Recommend prices for all products considering competing imported products and the potential for export and comment on the economic advantages and disadvantages of applying protective tariff.

Price List of Petroleum & Petrochemical Products

| Sl. No. | Petroleum & Petrochemical Products | Unit Price {In TK} | VAT { In TK} | Unit | Price including VAT {In TK} |
|----------------|---|---------------------------|---------------------|-------------------|------------------------------------|
| 1 | MS | 60.89 | 9.13 | Liter | 70.02 |
| 2 | HSD | 36.06 | 5.40 | Liter | 41.46 |
| 3 | High Octane Gasoline | 63.40 | 9.50 | Liter | 72.90 |
| 4 | Kerosene | 36.42 | 5.46 | Liter | 41.88 |
| 5 | LPG | 58850.00 | 8828.60 | MT | 67680.00 |
| 6 | LPG -- 12.50 Kg bottle | 926.00 | 54.00 | per bottle | 980.00 |

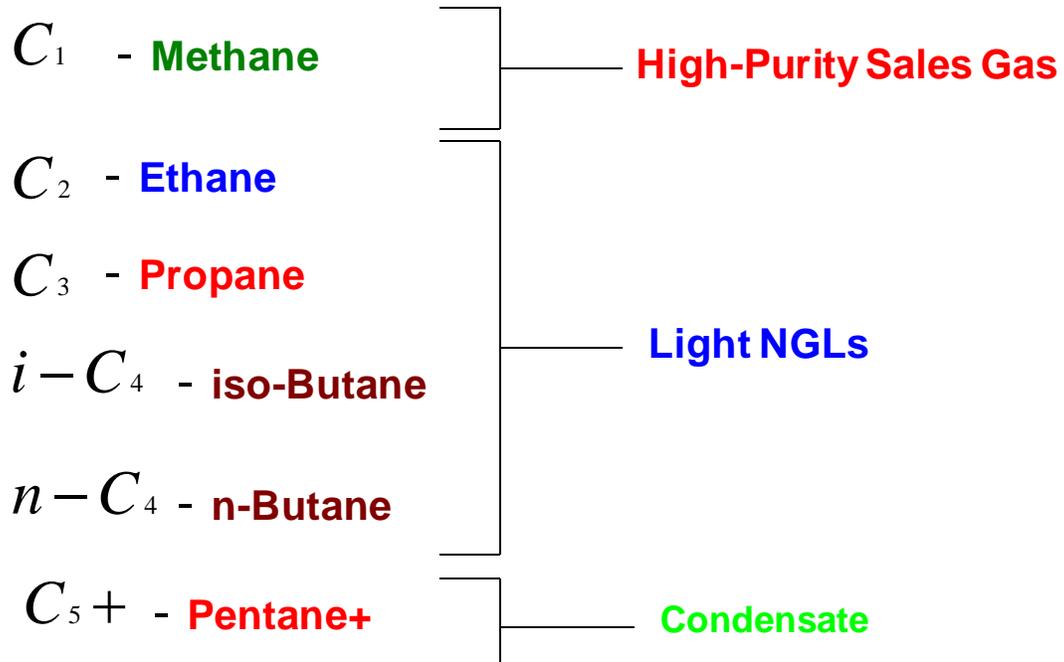
| | | | | | |
|----|---------------------------------|-------|------|-------|--------|
| 7 | Price of Pressure-Tested Bottle | | | each | 2800.0 |
| 8 | Octane Booster Additive | | | Liter | 30000 |
| 9 | Cetane Booster Additive | | | Liter | 250.00 |
| 10 | Polyethylene | | | kg | 90.00 |
| 11 | Polypropylene | | | kg | 100.00 |
| 12 | Formalin/Formaldehyde | | | Liter | 240.00 |
| 13 | Methanol | | | Liter | 300.00 |
| 14 | Ammonia | | | Liter | 180.00 |
| 15 | Benzene | | | Liter | 600.00 |
| 16 | Toluene | | | Liter | 560.00 |
| 17 | Xylene | | | Liter | 480.00 |
| 18 | MTT | 40.94 | 6.14 | Liter | 47.08 |

Above products with their corresponding prices were collected on January 2010. The proposed quantity of each marketable product as shown in pages 59 - 70, is based on the current market size of Bangladesh, neighboring markets as well as the capability of the straddle plant complex to produce such products.

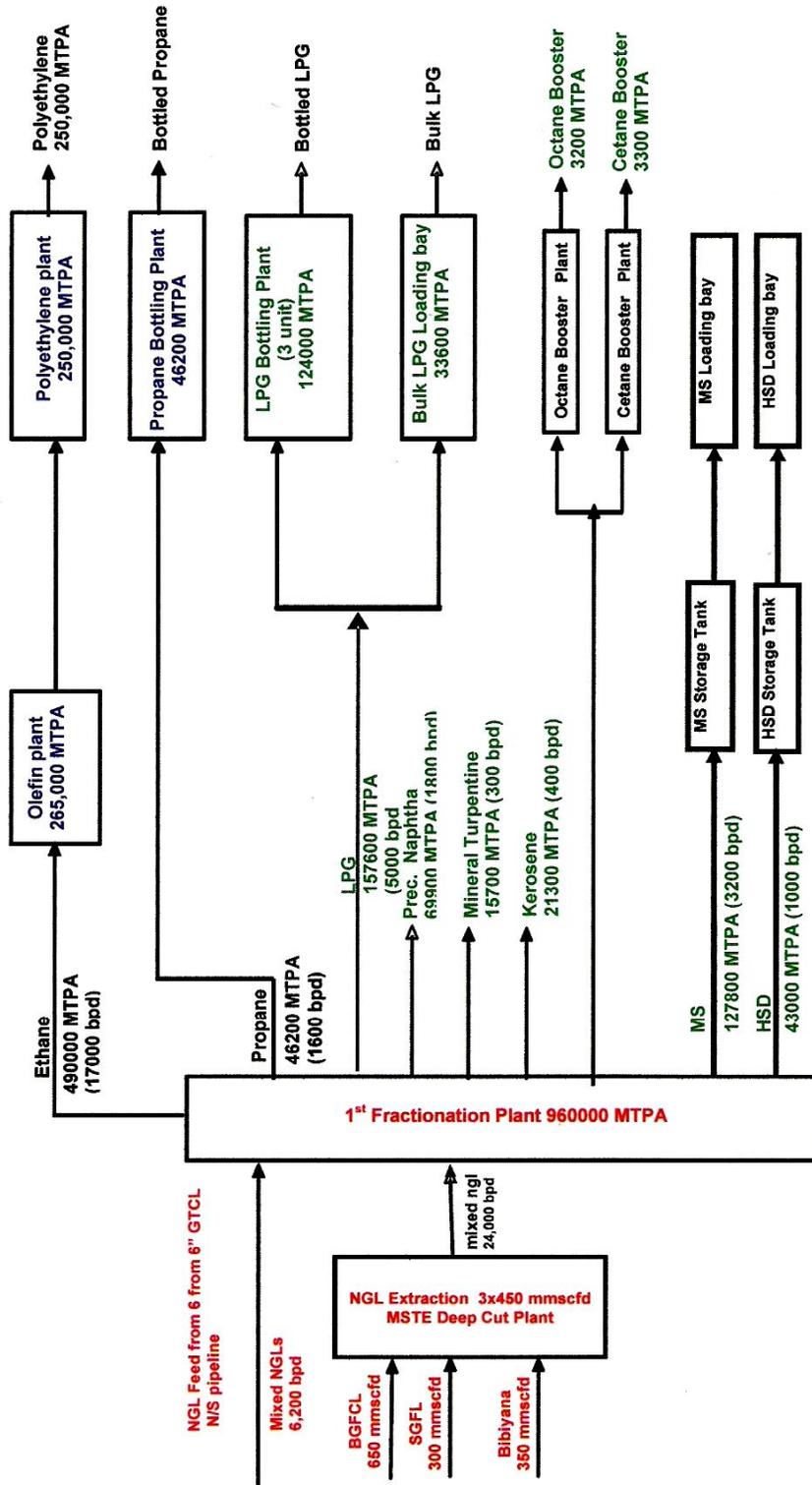
Applying protective tariff is good; however, it may not augur well with the products of this plant complex as it will create an atmosphere of protectionism. An active open-market competition would be better.

In line with the above information, a general list of imported machineries & equipment required for manufacturing above high-value products are given below. The purpose is to give the reader an idea of the major imported items for financing purposes.

Composition of the Inlet Feed Gas To The Straddle Plant



**CONCEPTUAL SCHEMATIC PROCESS FLOW DIAGRAM OF A STRADDLE PLANT
(PETROLEUM PRODUCTS) AT ASHUGANJ**



PETROLEUM PRODUCTS

| ITEMS | QUANTITY |
|---------------------------------|--------------|
| 1. High purity sales gas { 99 } | 1.2545 bscfd |
| 2. HSD | 30100 MTPA |
| 3. MS | 115800 MTPA |
| 4. Superior Kerosene Oil | 21000 MTPA |
| 5. LPG (Liquid Petroleum Gas) | 157600 MTPA |
| 6. Naphtha | 116000 MTPA |
| 7. MTT | 4100 MTPA |
| 8. Booster (Octane) additive | 3200 MTPA |
| 9. Booster (cetane) additive | 3300 MTPA |

Calculation

Basis of Calculation

- 12 month = 1 year = 330 days
- 159 ltrs = 1 bbl
- 1000 ltrs = 6.28 bbls
- 1MT= 6.28 bbls x density
- 1 bscf = 1mmscf x 10³

1. High purity sales gas (99%)

1. 30 bscfd - 0.455 bscfd
 1.2545 bscfd
 1.2545 x 30
 37.635 bscf / month
 1.2545 x 330
 413,980 bscf / year

2. MS

115800 MTPA
 9600 MT / month
 322 MT / day
 2,900 bpd
 2900 x 30
 87000 bbls / month
 2900 x 330
 957000 bbls / year

3. HSD

30100 MTPA
2500 MT / month
84 MT / day
700 bpd
700 x 30
21,000 bbls / month
700 x 330
231000 bbls / year

4. SKO (Superior Kerosene)

21000 MTPA
1750 MT / month
59 MT / day
500 bpd
500 x 30= 1500 bbls/month
500 x 330
165,000 bbl / year

5. LPG

2990 bpd
157600 MTPA
13000 MT / per month
437 MT / per day

6. Naphtha

116000 MTPA
9600 MT / month
320 MT / day
3000 bpd
990000 bbls/yr.

7. MTT

4100 MTPA
342 MT / month
12 MT / day
100 bpd
3000 bbls/month
33600 bbls /year

8. Booster (octane) additive

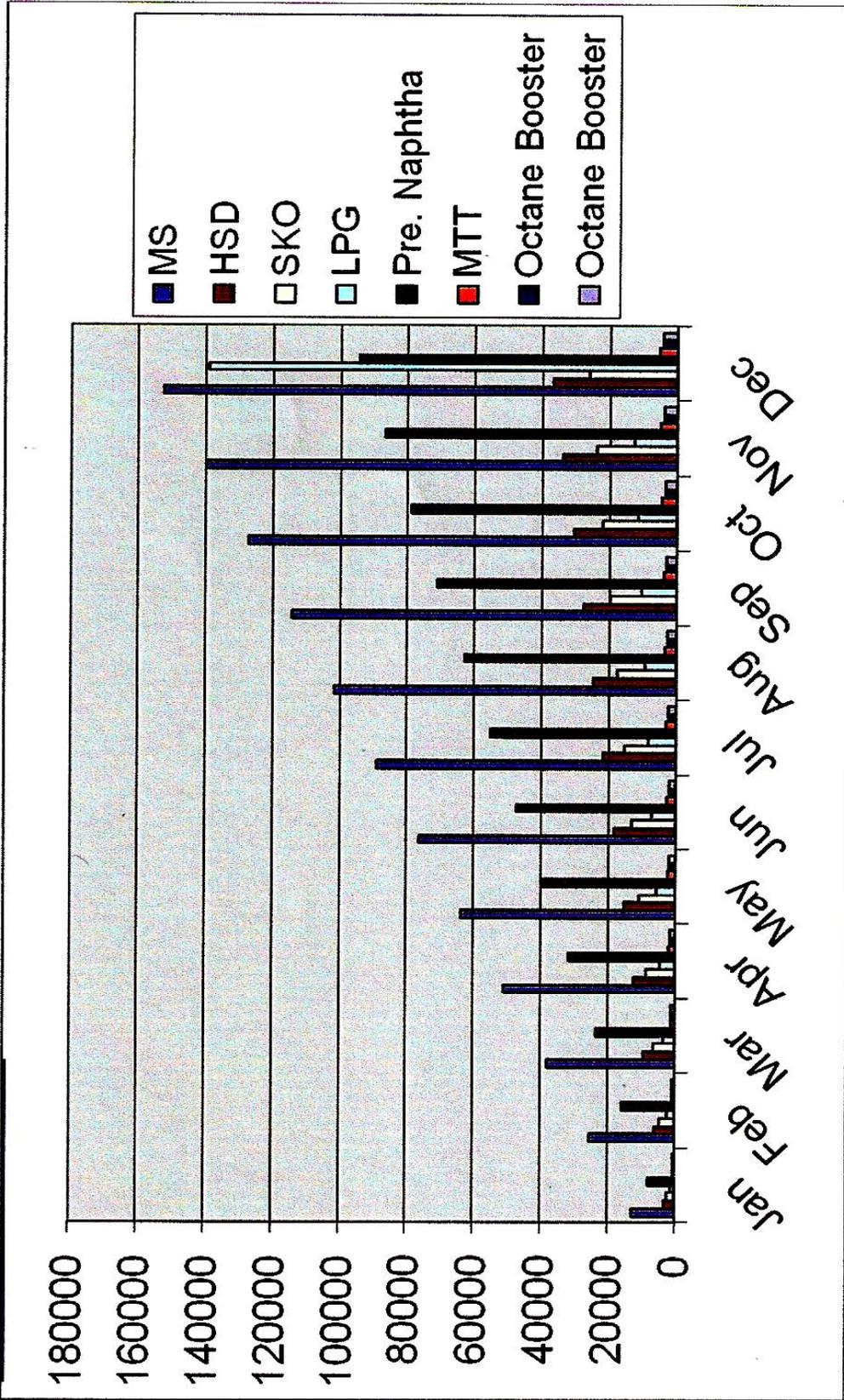
43200 MTPA
267 MT / month
9 MT / day
80 bpd
2400 bbls/month
26400 bbls/year

9. Booster (cetane) additive

3300 MTPA
275 MT / month
10 MT / day
80 bpd
2400 bbls/month
26400 bbls/year

BAR CHART

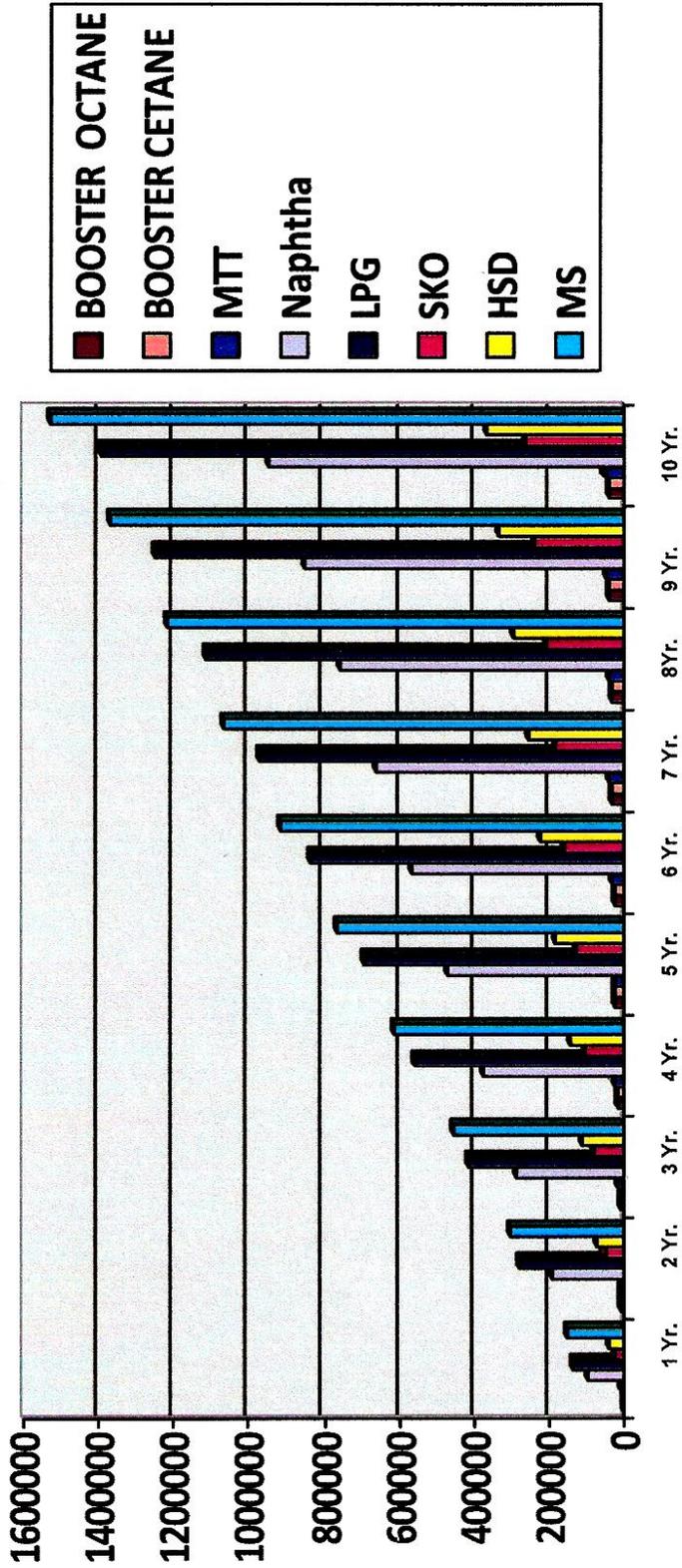
Figures are in MTPA



Monthly Cumulative Production of Petroleum Products Obtainable from Ashuganj Straddle Plants

Bar Chart

Figures are in MTPA



Yearly Cumulative Production of Petroleum Products Obtainable from Ashuganj Straddle Plant

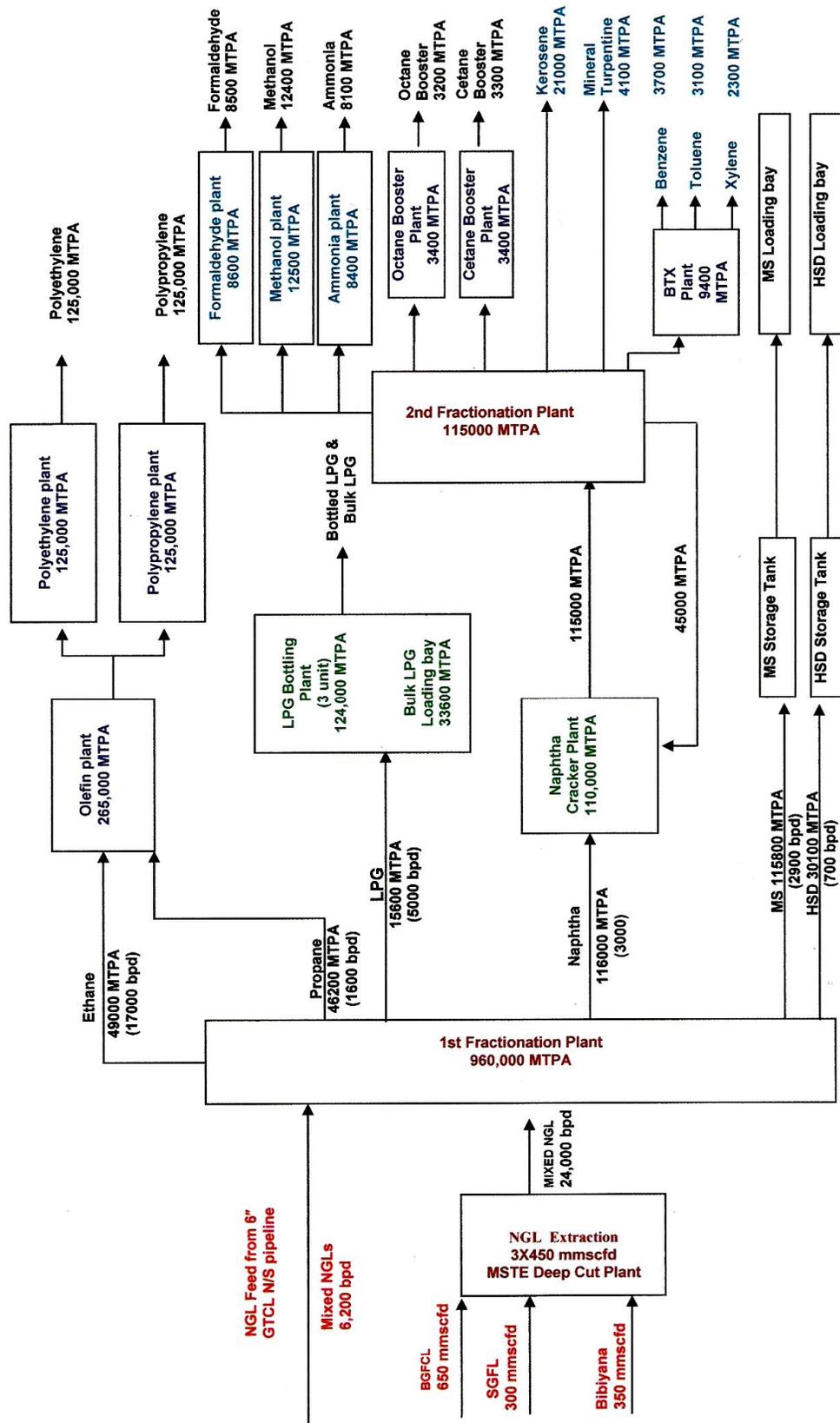
Comparative Statement Between the Products (Petroleum) of Straddle Plant and the similar products in Companies of Petrobangla.

Data are based on December 2009

Figures are in MTPA

| Petroleum Products Produced | Quantity from the Straddle Plants at Ashuganj | Quantity from companies Plants of Petrobangla | Quantity more in Straddle Plant | Remarks |
|-----------------------------|---|---|---------------------------------|---|
| MS | 115800 | 27740 | (+) 143540 | MS, HSD, SKO, LPG are produced less in the plants owned by the companies of Petrobangla. 100,000 (One Lac) MTPA Crude oil Naphtha is produced by Eastern Refinery Ltd. Chittagong. This naphtha can be used as feed stock in the Straddle plant complex for the production of more Petrochemicals. |
| HSD | 30100 | 25470 | (+) 4630 | |
| SKO | 21000 | 10590 | (+) 10400 | |
| LPG | 157600 | 3328 | (+) 154272 | |
| Naphtha | 116000 | Nil | (+) 116000 | |
| MTT (Mineral Turpentine) | 4100 | Nil | (+) 4100 | |
| Octane Booster Additive | 3200 | Nil | (+) 3200 | |
| Cetane Booster Additive | 3300 | Nil | (+) 3300 | |

CONCEPTUAL SCHEMATIC PROCESS FLOW DIAGRAM OF A STRADDLE PLANT (PETROCHEMICAL PRODUCTS) AT ASHUGANJ



PETROCHEMICAL PRODUCTS

| <u>ITEMS</u> | <u>QUANTITY</u> |
|------------------|-----------------|
| 1) Polyethylene | 125,000 MTPA |
| 2) Polypropylene | 125,000 MTPA |
| 3) Benzene | 3700 MTPA |
| 4) Toluene | 3100 MTPA |
| 5) Xylene | 2300 MTPA |
| 6) Ammonia | 8100 MTPA |
| 7) Formaldehyde | 8500 MTPA |
| 8) Methanol | 12400 MTPA |

Calculation

Basis of Calculation

- 12 month = 1 year = 330 days
- 159 ltrs = 1 bbl
- 1000 ltrs = 6.28 bbls
- 1 MT (Metric Ton)= 6.28 bbls x density

1. Polyethylene

125,000 MTPA
2,080 MT / month
75.76 MT / day
2300 bbls/day
71,300 bbls/month

2. Polypropylene

125,000 MTPA
2,080 MT / month
75.76 MT / day
2300 bbls/day
71,300 bbls/month

3. Benzene

3700 MTPA
300 MTPA
10 MT –day
80 bpd
2400 bbls/month
26400 bbls/year

4. **Toluene**

3100 MTPA
258 MT/ month
9 MT/ day
70 bpd.
2,100 bbls/month
23,100 bbls/year

5. **Xylene**

2300 MTPA
192 MT / month
6 MT /day
50 bpd
1500 bbls/month
16,500 bbls/year

6. **Methanol**

12400 MTPA
1030 MT / month
35 MT / day
300 bpd.
9,000 bbls/month
99,000 bbls/year

7. **Formaldehyde**

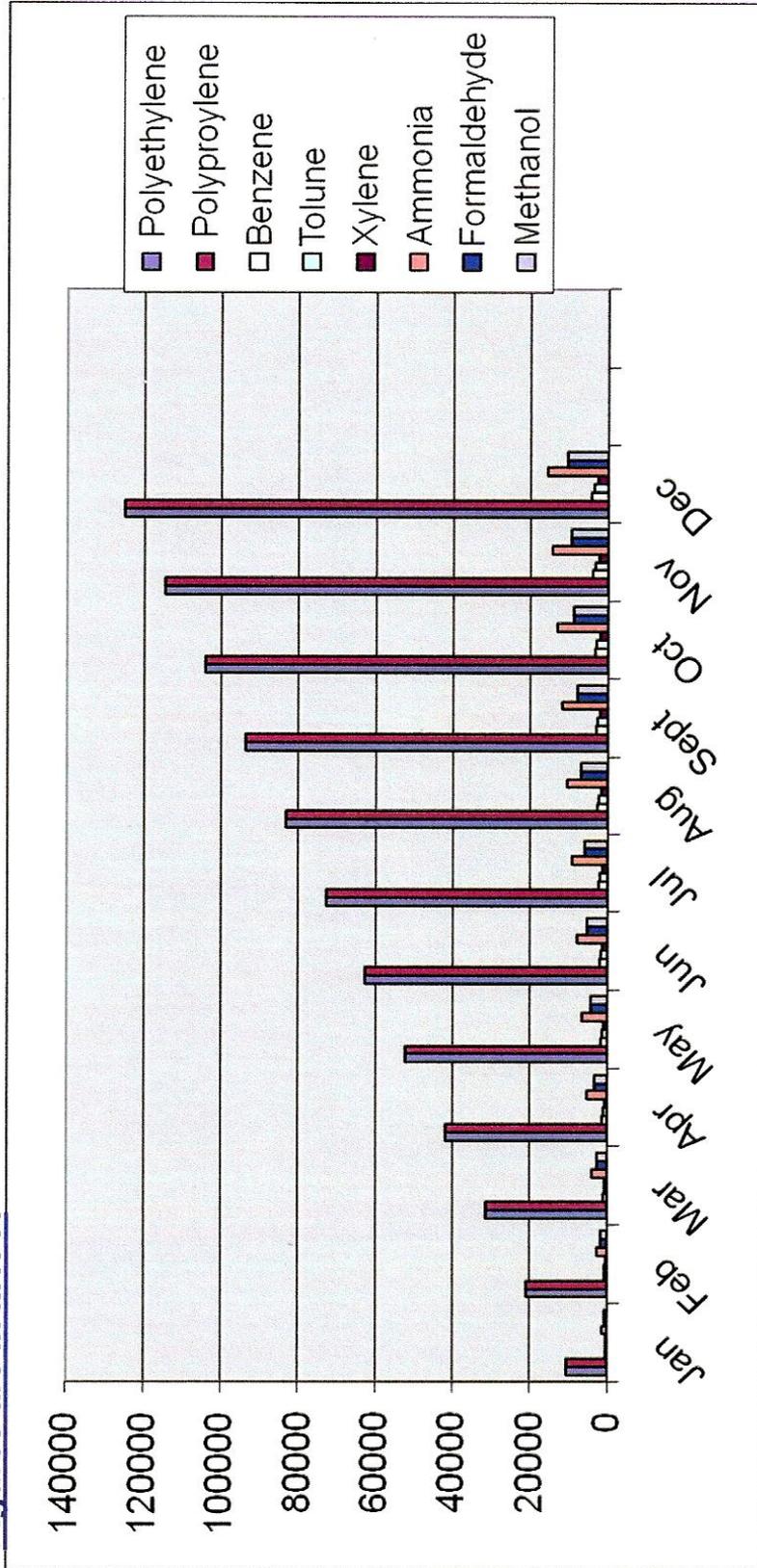
8500 MTPA
700 MT / month
24 MT / day
200 bpd.
6,000 bbls/month
66,000 bbls/year

8. **Ammonia**

8100 MTPA
675 MT / month
23 MT / day
200 bpd.
6,000 bbls/month
66,000 bbls/year

BAR CHART

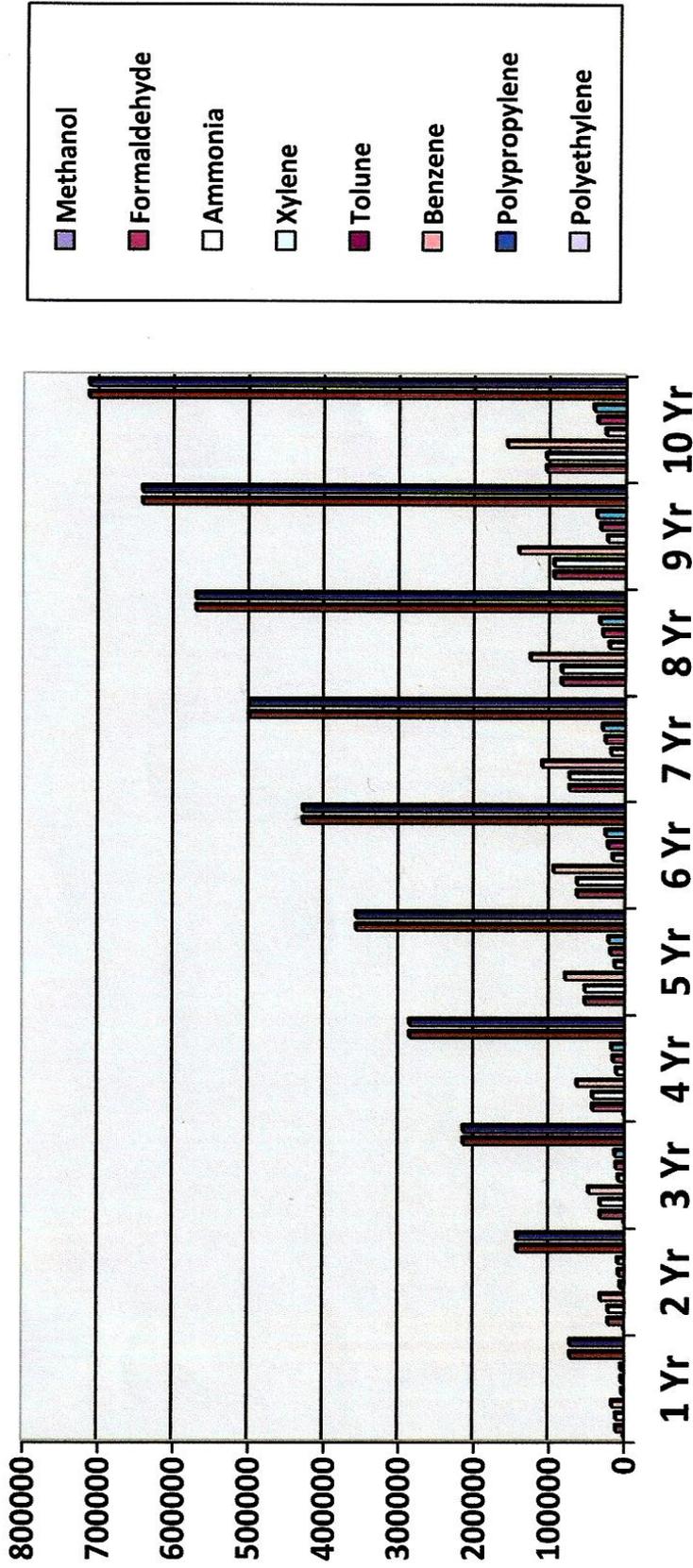
Figures are in MTPA



Monthly Cumulative Production of Petrochemical Products Obtainable from Straddle Plant Complex at Ashuganj.

Bar Chart

Figures are in MTPA



Yearly Cumulative Production of Petrochemical Products Obtainable from Ashuganj Straddle Plant Complex

Comparative Statement Between the Products (Petrochemical) of Straddle Plant and the similar products in Companies of Petrobangla.

Data are based on December 2009

Figures are in MPTA

| Petrochemical Products Produced | Quantity from the Straddle Plants at Ashuganj | Quantity from companies Plants of Petrobangla | Quantity . more in Straddle Plant | Remarks |
|---------------------------------|---|---|-----------------------------------|---------|
| Polyethylene | 125000 | Nil | (+) 125000 | |
| Polypropylene | 125000 | Nil | (+) 125000 | |
| Benzene | 3700 | Nil | (+) 3700 | |
| Toluene | 3100 | Nil | (+) 3100 | |
| Xylene | 2300 | Nil | (+) 2300 | |
| Formaldehyde | 8500 | Nil | (+) 8500 | |
| Methanol | 12400 | Nil | (+) 12400 | |
| Ammonia | 8100 | Nil | (+) 8100 | |

4.0 SITE VISIT(S), DATA COLLECTION AND ATTACHMENTS OF THE COLLECTED DATA HERETO

During the site visits, a lot of field data & information were collected which were helpful in preparation for this feasibility study. As such, they are included in this report as these data will be useful for any future studies, plans and as a reference for the implementation of this feasibility study or other studies that require these data.

5.0 ACKNOWLEDGEMENTS & REFERENCES USED IN PREPARING THE FEASIBILITY STUDY REPORT FOR SETTING UP OF A STRADDLE PLANT FOR NGL EXTRACTION AND FRACTIONATION AT ASHUGANJ

5.1 ACKNOWLEDGEMENTS

The Draft Feasibility Study Report for Setting Up a Straddle Plant for NGL Extraction & Fractionation at Ashuganj is an interesting one.

On conclusion of this feasibility study report, the resultant gain is quite important. The financial as well as the economic evaluations with regards to various aspects were optimistic. The IRR (Internal Rate of Return) is reasonably high, i.e. **28%** and other economic terms and calculations with regards to the project are highly positive.

As such, we can conclude that the Feasibility Study for Setting Up a Straddle Plant for NGL Extraction & Fractionation Complex at Ashuganj is highly feasible, technically & financially.

The aforesaid feasibility study has been made by a team comprising of engineers, financial analyst and officers of Pegasus international Sdn Bhd, Malaysia.

On behalf of our entire team , we like to express our deep gratitude to the many officials of Hydrocarbon Unit of Energy & Mineral Resources Division, Petrobangla, SGFL, BGFCL, RPGCL, TGT&DCL and Chevron {IOC}.

The team has visited the above-mentioned gas fields including Chevron's gas fields in greater Sylhet zone and collected data pertinent to production operations, projections & reserves.

The team, therefore, appreciate the co-operation of Petrobangla and its Companies including an IOC as well.

The team would like to extend its heartfelt thanks to Director General {DG} of Hydrocarbon Unit, Energy & Mineral Resources Division, who from time to time monitored our work and inspired the team to do our jobs as per the Terms of Reference of the project.

The team is grateful to the officers and staffs of the Hydrocarbon Unit, whose co-operation was vital in all the necessary steps during our study of the aforesaid project.

And lastly, we would like to give our sincere thanks and gratitude to the Director of Operations, Pegasus International for his co-operation in preparing this feasibility study.

Recommendation

Since the team found out that the capital cost of the imported machineries & equipment portion of this feasibility study is quite large, it is recommended that: if ever this project will be installed, constructed, tested, commissioned & the facilities turned-over to its owner/owners, it should be implemented in modules, i.e., Module-I shall consist of the **NGLs** Extraction Plant, Fractionation Plant, Polyethylene Plant, Polypropylene Plant, Naphtha stripper, Kerosene stripper, Precipitation Naphtha stripper, Mineral Turpentine stripper, Octane Booster Plant, Cetane Booster Plant & LPG Bulk & Bottling Plants, MS/HSD loading areas & Storage/Production Tanks. It can function on its own.

Module-II shall consist of a Catalytic Naphtha Cracker Plant, a second Fractionation Plant for the Crackates, BTX (Benzene/Toluene/Xylene) Plant, Ammonia Plant, Methanol Plant, Formaldehyde/Formalin Plant, MS/HSD loading areas & Storage/Production Tanks.

Imported Machinery & Equipment

- a). Extraction Plant / MSTE plant ----- 3 units X 450 mmscfd capacity each
- b). 1st Fractionation Plant ----- 900,0000 MTPA capacity
- c). 2nd Fractionation Plant ----- 110,000 MTPA capacity
- d). Bottling Plant ----- 3 units X 124,000 MTPA capacity each
- e). Olefins, Polyethylene & Polypropylene Plants --- 265,000 MTPA , 125,000 MTPA & 125,000 MTPA capacity respectively
- e). Octane Booster & Cetane Booster Plants ----- 3,500 MTPA & 3,100 MTPA capacity respectively
- f). Gas / Diesel Generator ----- 3 nos , 1,200 KVA capacity each
- g). Naphtha Catalytic Cracker Unit ----- 110,000 MTPA capacity
- h). Fractionation Tower for the Cracker Unit ----- 110,000MTPA capacity
- i). Stripper Column ----- 8,400 MTPA capacity
- .j). Formaldehyde, Methanol & Ammonia Plants ----- 8,300 MTPA, 8,300 MTPA & 12,200 MTPA capacity respectively
- k). Valves, pipes, fittings ----- Lots
- l). Storage & Production Tanks ----- Lots

5.2 References

- > LPG Study updated, Preliminary Report
Authored by: RMT Engineers Ltd., Canada

- > Gas Production Operations
Authored by: H.Dale Beggs. OGCI

- > Preparation and Development of Gas Sector Master Plan and Strategy for Bangladesh
Authored by: Wood Mackenzie Ltd. UK.

- > Natural Gas Processing & Transportation
Submitted to Strathclyde University, United Kingdom
Authored by: SM Kamal uddin

- > Energy Resources of Bangladesh, 1st Edition, June, 2005
Authored by: Dr. Badrul Imam

- > Strategic Gas Utilization Study for the People's Republic of Bangladesh dated January 2002
Authored by: S.H. Lucas & Associates Canada.

6.0 GLOSSARY AND ABBREVIATIONS

| Units of Measure (Abbreviation) | Extension | Units of Measure (Abbreviation) | Extension |
|------------------------------------|--|------------------------------------|--------------------------------|
| Bbl | Barrels | MWh | Megawatt -- 1000 kwh |
| bpd | Barrels per day | GW | Gigawatt--1,000 Megawatts |
| Btu | British thermal units | GWh | Gigawatt hour-1000 MWh |
| MMBtu | Million British thermal units | TOE | Metric Tons of oil Equivalent |
| Bcf | Billion Standard Ft ³ | TCE | Metric Tons of Coal Equivalent |
| Bscfa | Billion Standard Ft ³ /yr.. | C ₂ | Ethane |
| Bscfd | Billion Standard Ft ³ /Day | C ₃ | Propane |
| mmscfa | Million Standard Ft ³ /yr | C ₄ | Butane |
| mmscfd | Million Standard Ft ³ /day | C ₅₊ | Pentane and heavier NGL |
| Tscf | Trillion Standard Ft ³ | CC | Combined cycle power plant |
| J | Joule | CT | Combustion turbine |
| KJ | Kilojoule-0.9478 Btu. | CBM | Coal Bed Methane |
| MJ | Mega joules -947.8 Btu. | CNG | Compressed Natural Gas |

| | | | |
|--------|----------------------------------|------|--|
| | | | |
| GJ | Gigajoules –947,800 Btu. | D | Diesel |
| M | Meter | GT | Gas Turbine |
| Km | Kilometer | HFO | Heavy Fuel Oil |
| Mi | Mile- 1.62 km | HSD | High Speed Diesel |
| Mmscf | Million Standard Ft ₃ | HSFO | High Sulfur Fuel Oil |
| tonne | Metric Ton | IGCC | Integrated Gasification Combined Cycle |
| MTPA | Metric Ton per annum | IKO | Inferior Kerosene Oil |
| TPA | Metric Ton Per annum | LNG | Liquefied Natural Gas |
| TPD | Metric Ton Per day | LPG | Liquid Petroleum Gas |
| MMTPA | Thousand Metric Ton Per annum | MS | Motor Spirits |
| MMMTPA | Million Metric Ton Per annum | NGLs | Natural Gas Liquids |
| MMTPA | Thousand Metric Ton Per annum | NGV | Natural Gas Vehicle |
| MMMTPD | Million Metric Ton Per day | SKO | Superior Kerosene Oil |

| | | | |
|---------|---|-------|--|
| Kv | Kilovolt-- 1000 volt | ST | Steam turbine |
| kw | Kilovolt-- 1000 volt | LSFO | Low Sulfur Fuel Oil |
| kwh | Kilo watthour | HSFO | High Sulfur Fuel Oil |
| MW | Megawatt- 1000kw | Hydro | Hydroelectric |
| DC-MSTE | Deep-cut Molecular Sieve Turbo Expander | SCADA | Supervisory Control And Data Acquisition |
| HRSG | Heat Recovery Steam Generation | | |

| Commercial Abbreviation | Extension | Commercial Abbreviation | Extension |
|--------------------------------|-------------------------------------|--------------------------------|--|
| | | | |
| ADB | Asian Development Bank | USAID | United States Agency for International Development |
| CAPEX | Capital Expense | WB | World Bank |
| ECA | Export Credit Agency | CY | Calendar year |
| FDI | Foreign Direct Investment | FY | Fiscal year (ending June 30) |
| IFI | International Financing Institution | US \$1.00 | Tk70.00 |
| OPEX | Operating Expense | Tk 1.00 | US \$0.01428 |

| | | | |
|------|--|---------------|---|
| PPA | Purchase Power Agreement | Discount Rate | 14% (range 10 to 15%) |
| PSA | Production Sharing Agreement | BGFCL | Bangladesh Gas Field Company Limited |
| TDA | US Trade and Development | IOC | International Oil Company |
| TOR | Terms Of Reference | LPGCL | LP Gas Company Ltd. |
| BPDB | Bangladesh Power Development Board | PGC | Power Grid Corporation of India |
| GoB | Government of Bangladesh | RPGCL | Rupantarita Prakritik Gas Company, Ltd. |
| Gol | Government of India | SGFL | Sylhet Gas Field Limited |
| MEMR | Ministry of Power, Energy and Mineral Resources. | REB | Rural Electrification Board |
| PBS | Palli Bidyut Samities | RPC | Rural Power Company Ltd. |
| PGCB | Power Grid Company of Bangladesh | USG | U.S. Government |

7. QUERIES AND REPLIES DURING THE PRESENTATION OF THE FEASIBILITY STUDY FOR SETTING UP A STRADDLE PLANT FOR NGL EXTRACTION & FRACTIONATION AT ASHUGANJ

Consequence upon the above-mentioned subject, we would like to describe that on April 18, 2010, during the presentation of the aforesaid subject, many questions were asked by the attendees and answered by the Project team members accordingly. However, since some queries were made in writing; hence, there is a need to respond to those written queries and subsequently incorporate them in the final report of this feasibility study project.

The written queries and the replies are as follows:

| Queries | Response provided by the Consultant |
|---|---|
| 1}-If Naphtha produced from crude oil processing at ERL, is processed along with Naphtha produced from NGL Fractionation plant, one additional valuable product named Butadiene will be produced. Am I to understand that if Naphtha from only NGL Fractionation plant is cracked in the Naphtha cracker, there will be no production of Butadiene? | Regarding crude oil Naphtha from ERL, there will be separate Naphtha cracker Plant, from where butadiene will be produced. |
| 2}-There was a study some years back on the Feasibility of NG to olefins technology {ethane/propane cracking} and it was found that the process requires 70% more energy than the | NG is still at a low price in Bangladesh compared to other countries. In this country NG is selling by volume not in heating value. Even if we consider the |

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| <p>conventional Naphtha cracking for olefins. The ethane / propane cracking project feasible only when NG is available at a very low price say at \$ 0.70 to \$ 1.0 per G joules. Have you taken everything into consideration while choosing ethane / propane cracking {as per your best Conceptual flow Diagram} for olefin production for petrochemicals?</p> | <p>price of NG in heating value then some portion of ethane will be kept with NG then the heating value will increase and even then the proposed project will still be economically viable.</p> <p>Moreover, a recent survey of the plants with the technology owners such as Stone & Webster, Technip, Lummus, Samprogetti showed that introduction of new techniques, research & development of cost-reducing techniques proved that what was once an expensive technique is now very competitive economically.</p> |
| <p>3}-What is the feed material for proposed octane booster and cetane booster plants and what are these boosters?</p> | <p>Feed material for cetane & octane booster additives is the NGL/condensate itself. Derivatives from NGL's/Condensates may also be utilized as feedstock depending on what specific type/types of booster additives that the stakeholders will choose to manufacture in their respective process plants.</p> |
| <p>4)- Please take into consideration Market Analysis for</p> <ul style="list-style-type: none"> - Petrochemical Products - Petroleum Products | <p>In our feasibility study, the team made market survey as per requirement for both Petrochemical and Petroleum products, otherwise, the financial analysis of this project can never be prepared. Exhaustive market analysis or market analysis required for the preparation of the DPP or FEED (Front-End Engineering & Design) shall be carried out during project execution only.</p> <p>In this feasibility study, we are in consideration to get the required feed</p> |

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| | <p>stock from the upstream gas fields-both the IOC's & the NOC's. The individual field fractionation plant and the pipelines shall not be hampered, rather these will be necessary for the straddle plant project in the future. Even if the required feed stock of NGL /condensate as well as Liquefied Natural Gas may be imported from overseas in a competitive price.</p> <p>In the feasibility study, the produced petrochemical & petroleum products will first meet the demand of the country and then the products will be exported to the other countries in South Asia and Southeast Asia.</p> <p>Mode of transport will be by road & by river where applicable for individual product.</p> |
| <p>5) - Using of condensate pipe line for NGL transportation to RPGCL storage tanks in Ashuganj</p> <ul style="list-style-type: none"> - Existing NGL Fractionation plant at KTL - Existing condensate Fractionation Plant at KTL / Rashidpur | <p>This 6-inch high-pressure NGL's (NGL + Condensate) pipeline was originally designed to handle/transport high-pressure NGL's from Sylhet (KTL) area to Ashuganj in Brahmanbaria. Till now, its design life is still valid. The only problem is that some miscreants drilled holes in certain portions of the high-pressure pipeline. Not the entire length of the pipeline has holes drilled by those miscreants. Hence, the pipeline can still be rectified by using hot-tapping repairs techniques. This technique includes making a gooseneck connection & isolate or cut-off the drilled portions of the pipeline. Another technique is to hot-tap the drilled portion, clamp the portion with a similar-high-pressure casing, hot-weld, hydro-test & then put it back on-line. This high-pressure pipeline was NEVER COMDEMNED by PetroBangla;</p> |

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| | <p>otherwise, it would not have been used continuously till now in transporting condensates from KTL to the RPGCL storage tanks.</p> <p>For the existing pipelines for NGL fractionation at KTL as well as that used for the condensate fractionation plant in Rashidpur, they shall be operated as usual. If there will be a requirement to upgrade their respective handling/transporting capacities in the future, then they can be upgraded accordingly.</p> |
| <p>6)- Marketing end products</p> <ul style="list-style-type: none"> - By which Authority - Mode of Transportation for Local/Export | <p>Companies under Petrobangla shall have the authority/authorities to manufacture & market the petroleum-related products. Petrochemical-related products may be manufactured by Bangladesh Petrochemical Corporation and marketing to be done by affiliated companies thereof.</p> <p>Mode of transport for local market will be same as existing petroleum products and petrochemical products (such as urea) by river and by land. Bulk tankers for liquid products (such as ammonia, methanol, formaldehyde, benzene, toluene & xylene may be utilized.</p> <p>For export, packaging techniques that are acceptable to the international maritime transport system shall be used and MSDS (Materials Specifications & Descriptions Sheets) must be included. Item classification shall be strictly</p> |

included thereof for safe handling, storage & movement in the international ports of call.

8.0 THE COMMENTS OF PETROBANGLA AND RESPONSE MADE BY THE CONSULTANT ON THE DRAFT FINAL REPORT OF THE FEASIBILITY STUDY FOR SETTING UP A STRADDLE PLANT FOR NGL EXTRACTION & FRACTIONATION AT ASHUGANJ.THE WRITTEN RESPONSES OF THOSE COMMENTS SUBSEQUENTLY INCORPORATED IN THE FINAL REPORT OF THIS FEASIBILITY STUDY.

The comments and the responses are as follows:

| Comments of Petrobangla | Responses made by Consultant |
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| <ul style="list-style-type: none"> • The mentioned straddle plant's viability is highly dependent on assumed steady feed raw materials requirement. The report assumed a minimum supply of 1300 mmcsfd feed gas (350 mmcsfd from Bibiyana gas field , 650 mmcsfd from BGFCL's Habiganj Field and 300 mmcsfd from SGFL's Rashidpur/Kailastilla/Haripur /Chevrons's Jalalabad/Moulavibazar gas fields) Supply of gas from Habiganj gas field at the rate of 650 mmcsfd is confusing as the field is currently producing at about 260 mmcsfd . Besides Bibiyana field is currently supplying gas at the rate of 650-700 mmcsfd whereas consideration of 350 mmcsfd (minimum) rate for the straddle plant is also not clear. Further to that there is also consideration of 6200 bpd mixed NGL feed for straddle plant from different fields. At present mixed NGL are being used by different entities as feed for producing LPG, MS, Kerosene, HSD etc. The report however does not mention whether the above present usage of NGL need to be curtailed to feed the NGL to straddle plant. It may be mentioned that the steady | <ul style="list-style-type: none"> • We have collected Gas figures from concerned Gas Fields during 17-19 November 2009 & 29-30 December 2009. However during preparation of Petrobangla's Comments (during August 2010) gas production figures of different gas fields changed. Recently the Bibiyana Gas Field is producing 700 mmcsfd gas instead of 350 mmcsfd. BGFCL's Habiganj Gas Field produces 260 mmcsfd instead of 650 mmcsfd. In SGFL and Chevron's Moulavibazar and Jalalabad Gas Fields, the gas production was 300 mmcsfd, presently it is more than 340 mmcsfd. Hopefully they will be able to produce more gas in the near future. In those respect we can re-arrange the Gas input in the aforesaid straddle plant as follows: Straddle plant's feed stock is 1300 mmcsfd gas from North- South pipeline with the following assumed break up- <ul style="list-style-type: none"> ▪ 700 mmcsfd from Chevron' Bibiyana Gas Field. ▪ 260 mmcsfd from BGFCL's Habiganj Gas Field ▪ 340 mmcsfd from SGFL (Rashidpur, Kailashtilla, Haripur) & Chevron's |

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| <p>supply of assumed quantity of gas and mixed NGL may not be sustainable over the project life (25 years) given the performance of the concerned gas fields. So the techno economic viability of the Straddle plant may be analyzed further on the basis of different supply scenario of raw materials.</p> | <p>(Jalalabad, Moulovibazar Gas Fields).</p> |
| <ul style="list-style-type: none"> It has been mentioned that if there is supply shortage of mixed NGL, government may have to import NGL to make the plant viable but no economic analysis has been provided for the case which may be included in the report. | <ul style="list-style-type: none"> In our Feasibility study, the Team made market survey for both Petrochemical and Petroleum products, otherwise the financial analysis of this project could not be prepared. Exhaustive market analysis required for the preparation of DPP or FEED (Front End Engineering & Design) shall be carried out during project execution. In this Feasibility study, we considered feed stock from the upstream gas fields of both IOC's & NOC's. The existing fractionation plants of individual fields shall not be affected by the proposed Straddle Plant. If the required feed stock of NGL /Condensate as well as Liquefied Natural Gas is required to be imported from overseas, economic analysis will be done during preparation of DPP. |
| <ul style="list-style-type: none"> In the report for cost analysis prices for machineries & equipment has been estimated from the book "Strategic Gas Utilization study for the People Republic of Bangladesh", authored by SH Lucas and Associates, January 2002. However justification of considering the above basis and their comparability with the present global prices may be included in the report. | <ul style="list-style-type: none"> We considered the cost analysis prices of machineries & equipment as per current international price. A recent survey among the technology owners such as Stone & Webster, Technip, Lummus and Snamprogetti showed that introduction of latest technology through Research & Development proved to be successful. Technology, once supposed to be expensive is now very competitive. |
| <ul style="list-style-type: none"> In the report it has been stated that prices of all petroleum and petrochemical are furnished considering competing imported | <ul style="list-style-type: none"> In our feasibility study, the Team made market survey as per requirement for both Petrochemical and Petroleum products. |

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| <p>products. In this regard imported products prices should have been placed sidewise to have a comparison.</p> | <p>Exhaustive market analysis required for the preparation of the DPP or FEED (Front-End Engineering & Design) shall be carried out during project execution.</p> |
| <ul style="list-style-type: none"> • The subject Straddle plant requires a huge amount of investment. So the products market is also equally important as of ensuring of steady supply of raw materials. There should be a stable market of end product for both local and foreign market and substantial elaboration of market analysis may be included in the report. | <ul style="list-style-type: none"> • Exhaustive market analysis required for the preparation of the DPP or FEED shall be carried out during project execution. |