CHAPTER-8
TECHNO-COMMERCIAL ANALYSIS OF AGG

8.1 INTRODUCTION

A gas grid is a collection of gas transportation pipelines from gas producing fields to consumption centers. Gas pipeline is the most convenient, reliable and feasible way of transporting natural gas. Once built, the pipeline operates for years with minimal operating and maintenance cost. The pipelines are designed for 25 – 30 years.

Asian gas grid is envisaged to consist of long distance international pipelines from gas producing countries to consuming countries in Asia. The pipelines are established mostly through available land connections among the countries, and are called onshore pipelines. Since the distance involved exceeds 1000 km, gas quantity and size of the pipelines are also quite large. For consumption of the gas within the countries, further domestic pipelines leading to the consuming plants are required to be laid.

In the current study, major gas producing countries considered are Iran, Turkmenistan, Kazakhstan, Myanmar and to some extent Bangladesh. Major consuming countries are India, China, and Pakistan. Some of the major limbs proposed are Iran-Pakistan-India (IPI), Turkmenistan-Afghanistan-Pakistan-India (TAPI), Kazakhstan- China and India-Bangladesh-Myanmar-China.

The scope of the current study is to establish technical and commercial feasibility of the individual limbs with respect to established parameters and standard assumptions.

8.2 OBJECTIVE OF THE ANALYSIS

The objective of the analysis is to define and establish technical parameters of the various limbs of the grid. Based on the available gas and a feasible selected route, the gas pipeline system is designed with pipeline sizing and compression facilities. The objective is to identify various viable options and carry out techno-commercial study to find the optimized option among the identified alternatives. Sensitivity to the changes in major parameters is also analyzed.

8.3 APPROACHES TO THE STUDY

Analysis was made to identify and work out various alternative technical parameters of long distance gas transportation systems. Pipeline sizing, pressure calculations, compression requirements, fuel consumption etc. were been carried out with the help of industry established Gas equations.

Investigations were also carried out to find the optimum technical and economical solution for long-distance gas transportation systems. All essential design factors were considered like pipeline diameter, suction and discharge pressure of compressor stations and spacing and numbers thereof, gas composition and yield, strength of pipeline material, as well as specific investment cost of pipe material, maintenance and fuel gas.

The study involved:

1. Finding out the source, destination, amount of gas to be transported en-route and to the destination, off-take points with amount of off-take

2. System Design with respect to establishing size of pipeline, spacing and power requirement of compression facilities, establishing spacing and requirements of various facilities namely sectionalizing valve stations, intermediate pigging stations, metering facilities etc.

3. Finding out the capital expenditure (CAPEX) and operating expenditure (OPEX) of various identified options, and carrying out economic analysis to find the optimum option. Investment analysis was carried out through one of the most respected present day methods - Internal Rate of Return (IRR) method.

8.4 BASIC DATA & ASSUMPTIONS

As in any technical and commercial study, the size and complexity of the current study on AGG pipeline involves extensive amount of parameters, data and assumptions. While some of them are listed here, additional assumptions will be mentioned in subsequent relevant parts of the study. It is appropriate to mention here that the study represents a base case for the data for which it has been carried out. Any variation in results and/or sensitivity of some of the parameters can be analyzed appropriately through changing values of those parameters.

1. Standard Conditions:

For the gas the following API Standard Conditions have been considered.

a) Standard Pressure : 101.325 KPa

b) Standard Temperature : $15^{o}C$

2. Typical Gas composition and characteristics :

Gas Component	**Concentration (mole %)**
Methane (CH_4)	91.15
Ethane (C_2H_6)	5.08
Propane (C_3H_8)	0.87
I- Butane (I- C_4H_{10})	0.10
N- Butane (N-C_4H_{10})	0.13
I- Pentane (I- C_5H_{10})	0.003
N-Pentane (N-C_5H_{10})	0.002
N-Hexane	0.003
Heptane	0.003
Octane	0.008
Nitrogen (N_2)	0.3
Carbon Dioxide(CO_2)	2.35
Total	100.00

Table: 8.1 Typical Gas Composition of Natural Gas Considered for Transportation

3. Additional typical gas characteristics:

Gas Property	**Unit**	**Value**
Specific Gravity	------------	0.68
Molecular weight	Kg/Kmole	19.69
Heating Value	Kcal/SCM^3	9000

Table:8.2 Additional Typical Gas Characteristics

The most relevant assumptions are listed Table 8.3:

Description	**Value**
Design Life	30 Years
Pipeline Design Pressure	98 bar
Maximum Allowable Operating Pressure	98 bar
Minimum arrival pressure	60 bar
Pipeline size	56 / 48 / 42
Min. temperature	0 ° C
Max. Temperature	60 ° C
Applicable Standard – Design / Line pipe / Construction	ASME B 31.8 / API 5L / API 1104
Steel Grade	API 5 L Grade X 70
Corrosion Allowance	None
Design factor	As per class location, details in system design section
Pipeline Internal coating	Considered for flow (~ 60 – 80 micron)
Pipeline external coating	3 Layer PE Coating considered for corrosion prevention
Cathodic protection	Impressed current cathodic protection for the design life
Pipeline Depth of Cover	As per ASME, minm. 1 m below ground level

Table: 8.3 Basic data and assumptions

Further assumptions, as and when taken, are detailed in the relevant sections.

8.5 ROUTE SELECTION

Route selection is a process of identifying constraints, avoiding undesirable areas and maintaining the economic feasibility of the pipeline. The ideal route, of course, would be a straight line from the origin to the terminal point, while at the same time, pass as close as possible to the demand centers. Physiographic, environmental, design and construction constraints usually alter the route. A pipeline route should be carefully selected at the beginning itself based on various considerations. Cost of diversion of large size pipeline is huge. Passey & Wooley have suggested the model of route selection as shown in Exhibit 8.1.

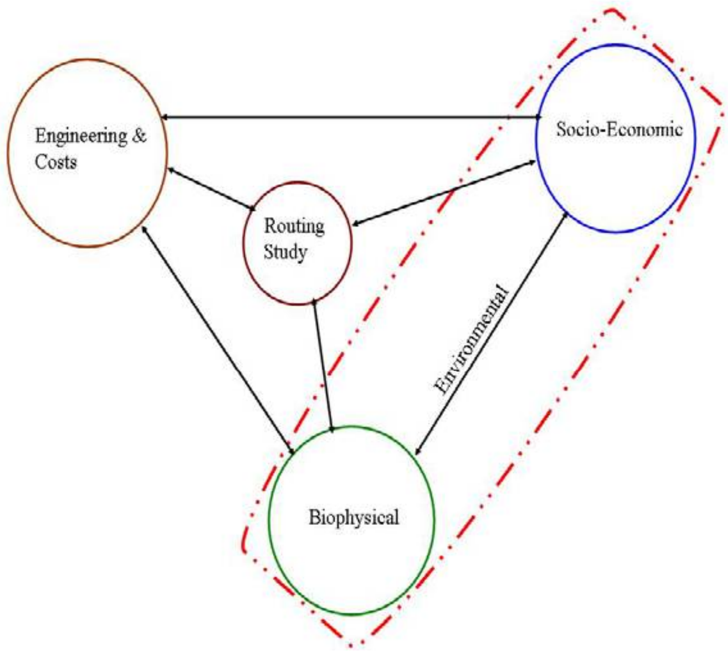


Exhibit:8.1 Major Considerations During All Phases of Route Selection

The following factors must be considered prior to selecting the optimum route for the pipeline.

- Cost efficiency
- Proximity to gas demand centers
- Pipeline integrity
- Environmental impacts
- Public safety
- Land-use constraints
- Restricted proximity to existing facilities

In our current study preliminary route has been selected based on the following methodology:

- Gas source has been identified

- Published Google map, with appropriate resolution is referred.
- Pipeline route is marked considering the following:
    - Minimum distance is traversed from the source to the end point.
    - Mountain, deserts, forests are avoided as best possible
    - The pipeline is taken across or as close as possible to the demand centre en-route
- Additional length tolerance has been added to the table top distances. For the purpose of current study, a 5 percent tolerance has been considered. Since the Asian Gas grid limbs are quite long (in excess of 1000 km), the assumption might have problem for inter point distances, but it holds good for the entire grid line on statistical level.
- Cumulative and inter-point distances – both actual table top and assumed - are listed. Source, tap-off and end points have been identified in these lists.

8.6 GAS QUANTITY AND THROUGHPUT DEVELOPMENT

Gas quantity from individual sources has been considered from the data in the previous chapter of Demand Supply Analysis, which are taken from "*Gas Intelligent Report*". Quantity has been considered large enough to be viable for transporting through long distance pipeline.

Tap-off of suitable quantity, as outlet, has been considered for important commercial cities en-route the pipeline. Tap-off for inlet quantities has been considered enroute the sources. These are listed in the appropriate places. Minimum arrival pressure is considered as 60 bar, both at any outgoing tap-off location or at destination.

A realistic throughput development for the design capacity is considered in the following manner:

1st year:	30 %
2nd year:	50 %
3rd year:	80 %
4th year:	100 %

8.7 SYSTEM DESIGN

A long-distance pipeline system is considered as a long string of pipeline sections with numerous intermediate compressor stations as shown in Exhibit 8.2.

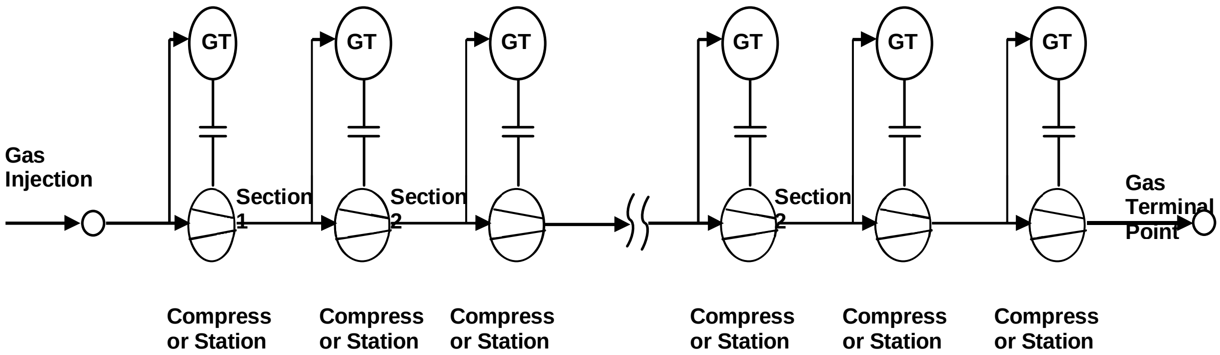


Exhibit:8.2 Schematic of a Long-Distance Gas Transportation System

The compressor stations are driven by gas turbines using the transported natural gas for own gas consumption. As the gas passes through a pipeline section, pressure reduces. This pressure is boosted up from an appropriate level by compressors located at strategic spacing. With increased pressure downstream of compressors, gas again travels through the next section till the pressure drops to a defined level where it is compressed again. This continues until it reaches the destination at a defined pressure.

The higher the diameter of the pipeline, the less the pressure drop for transporting a specified quantity, and hence less number of compressors are required. Similarly, if the diameter is smaller, then the compressors required will be more. Capital cost of high diameter pipelines increases exponentially while capital the cost of compressors increases less. However, operation and maintenance cost of pipelines are low and that of compressors quite high. Hence, there is a trade off where a combination of pipeline diameter and compressors are optimum - at least among the available alternatives.

The current study identifies various such alternatives through Hydraulics study. Detailed methodology of how the hydraulics studies were carried out, is given in the subsequent sections.

Along with the pipelines and compressors, the subsequent sections also give design and details of various pipeline facilities, like Sectionalizing Valve (SV) Stations and Intermediate Pigging Stations, Cathodic Protection, Supervisory Control and Data Acquisition System (SCADA) and telecommunications.

Hydraulics study – Pressure Profile Calculation

Hydraulic study and pressure drop calculation has been carried out with industry established complex gas equations, namely Panhandle A Equations.

Gas Properties

The calculations of the gas phase behavior are based on the equation.

$$P.V = m.R.T.Z$$

Where,

P = Gas Pressure (Pa)
V = Gas Volume (m^3)
M = Gas Mass (Kg)
R = Special gas constant of gas mixture with R = R_o/ M
R_o = 8.314 J/ Kmole / ^oK Universal gas constant
M = mole weight of the gas mixture (kg / Kmole)
T = Gas Temperature (^oK)
Z = Real Gas Factor

Pressure Drop Calculation

The **Panhandle A** was developed in 1940 and is used in natural gas pipelines. For low flows, low pressures, or short pipes, they may not be applicable. This equation was developed from the fundamental energy equation for compressible flow, but has a special representation of the friction factor to allow the equation to be solved analytically. The general form of the Panhandle A equation is as follows,

$$Q_{sc} = 1.198 * 10^7 *(T_b / P_b)^{1.0788} * [(P_1^2 – P_2^2 * d^{4.854})] / (\gamma^{0.8541} * L * T_m * Z_m)]^{0.5394} * (E)$$

Where,

Q_{sc} = Gas flow rate (MMSCMD)
T_b = Base temperature (^oK)
P_b = Base pressure (Kpa)
P_1 = Inlet pressure (Kpa)
P_2 = Outlet pressure (Kpa)
d = Inside diameter of pipe (m)
γ = Gas specific gravity
L = Pipe length (m)
T_m = Mean absolute temperature of line (^oK)

Z_m = Mean compressibility factor
E = Pipeline efficiency

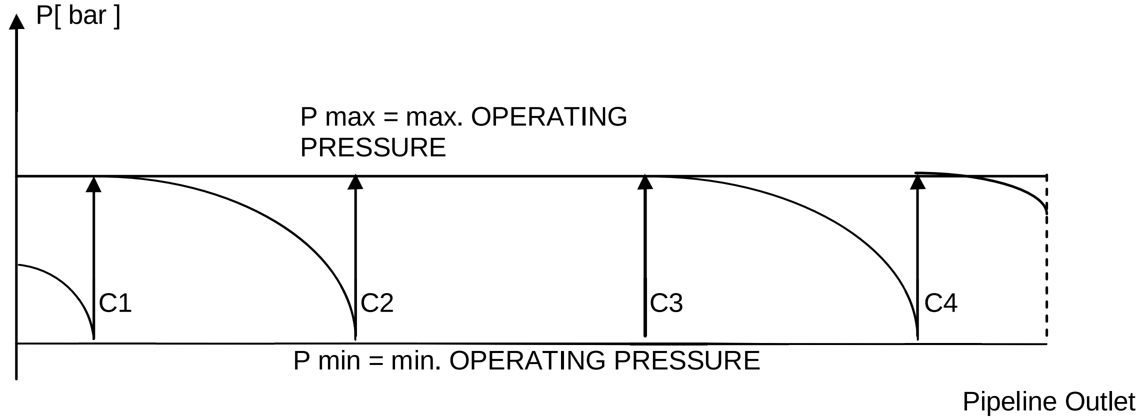


Exhibit 8.3 Schematic Sketch of Pressure Drop Calculatıon

Starting from a give pressure at the end of the pipeline system, the gradients and the number of compressor stations are calculated by using Panhandle A.

Equivalent Diameter

When two pipelines are in parallel or looped then the equivalent diameter of the Panhandle A equation is given as,

$$d_e^{2.618} = d_A^{2.618} + d_B^{2.618}$$

Where,

d_e = Equivalent diameter
d_A = Diameter of Pipe A
d_B = Diameter of Pipe B

Calculation of Compressibility Factor, Z

In the above Panhandle equation, compressibility factor Z value is calculated. Z value depends on Temperature, Pressure and Critical Pressure and Critical Temperature. Critical Pressure and Critical Temperature are in turn, dependant on gas properties. For the following properties of gas, Z value is calculated here.

Gas Properties:

Specific Gravity	0.68
Mole Fraction of N2	0.1
Mole Fraction of CO2	0.08
Mole Fraction of H2S	0.02

Curve of calculated value of Z, at 25° C, against various pressures is as shown in Exhibit 8.4.

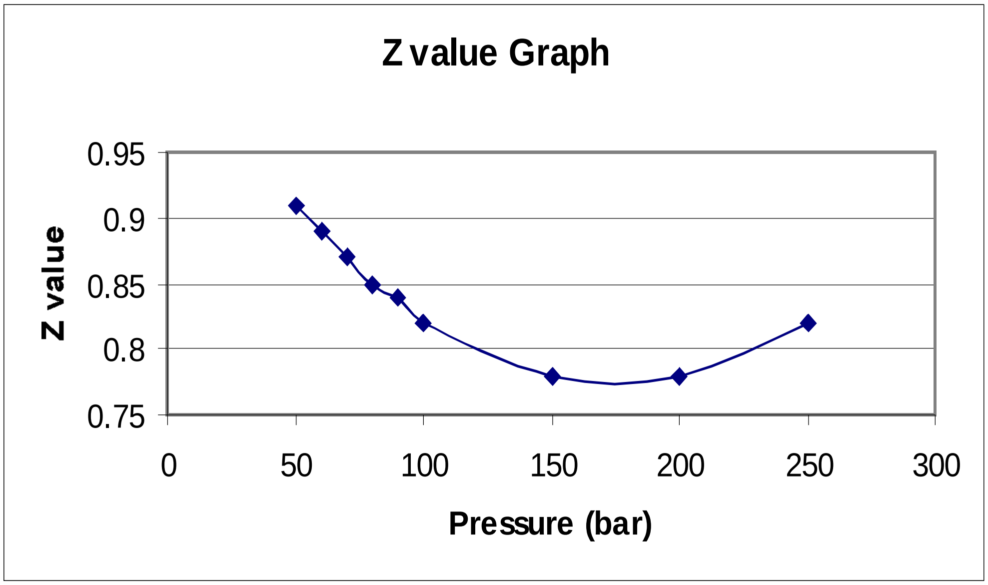


Exhibit:8.4 Z-Value Graph

Hence, it is seen that at a particular temperature, Z-value is a U-shaped curve and at a temperature of 25°C, the inflexion point is somewhere at 175°C. Ideally the mean Z- value should be taken. Mean Z-value Zm, is mean of values at inlet and outlet pressure. Since, outlet pressure is to be found out, and finding the mean would be an iterative process, Mean is calculated based on possible range of Outlet pressure. This is a good approximation and has been used in the current study.

Pipeline Wall Thickness Calculation

The pipeline wall thickness calculation was performed according to standard ASME B31.8, depending in first respect on the maximum operating pressure, the pipeline diameter and the pipe material selected, including a design factor based on the class location. A weighted value for wall thickness has been considered.

P = (2 S t) x F* E* T / D

Where,

D = Outside diameter of pipe (inches)
E = Longitudinal joint factor (=1 for API 5L SAW Pipe)
F = Design factor
P = Design pressure (psi)
S = Specified minimum yield strength (psi)
T = Temperature derating factor
t = nominal wall thickness (inches)

Location Class	**Design Factor(F)**
Location Class 1	0.80
Location Class 2	0.72
Location Class 3	0.50
Location Class 4	0.40

Table:8.4 Basic Design Factor

TEMPERATURE		**DERATING FACTOR *T***
°F	**°C**	
250 or Less	121 or Less	1
300	149	0.967
350	177	0.033
400	204	0.9
450	232	0.867

Table:8.5 Temperature Derating Factor for Steel Pipe

For our study we have considered that 90 percent of the pipeline passes through Class 1 , 5 percent through class 2 and remaining 5 percent through class 3. Since these are cross country pipelines avoiding population, this is a good approximation. Accordingly, a weighted wall thickness is calculated. This weighted wall thickness is considered for both pressure drop calculations and cost estimation.

Gas Compression

Compressors are required to provide the pressure in gas pipelines to transport a given volume of gas from source to destination. During the process of compressing the gas from inlet conditions to the necessary pressure at the discharge side, the temperature of the gas increases with pressure. Sometimes the discharge temperature may increase to levels beyond the maximum that the pipeline coating can withstand. Therefore, cooling of the compressed gas will be necessary to protect the pipeline coating. Cooling also has a beneficial effect on the transported gas, since cooler gas results in a lower pressure drop at a given flow rate. This in turn will reduce the required compressor power.

Compressor Power

The compressor compresses the natural gas and raises its pressure (and its temperature) to the level required to ensure that the gas will be transported from point A to point B, such that the required outlet pressure can be maintained. The higher the outlet pressure at B, the higher will be the pressure required at A. This will cause the compressors to work harder. The energy input to the gas by the compressors will depend upon the compression ratio and gas flow rate, among other factors. We can calculate the necessary compressor power, from the energy input to the gas.

Compressor head is measured in J/Kg. The compressor power can be calculated as follows.

STEP -I Determination of Exponent:

$$\frac{n-1}{n} = \frac{k-1}{k} * \frac{1}{\eta_p}$$

STEP- II Calculation of Mass Flow Rate:

$$m = \frac{P_s * Qs * MWg}{Z * 24 * 8.314 * T_s}$$

STEP-III Calculation of Head:

$$H_p = \frac{Z_{avg} * R * T_i}{MW_g} * \frac{[r^{n-1/n} - 1]}{(n-1/n)}$$

STEP- IV Calculation of Compressor Power:

$$P = \frac{m * Hp}{3600 * \eta p} + \text{Mechanical Losses}$$

Where,

P_s = Standard pressure (KPa)
Q_s = Gas flow rate (MMSCMD)
m = Mass flow rate (kg/hr)
T_s = Standard temperature (^oK)
T_i = Initial temperature (^oK)
MW_g = Molecular weight of the gas = 18
Z = Compressibility factor
Z_{avg} = Average compressibility factor
η_p = Polytropic efficiency
k = Ratio of specific heats
r = Pressure ratio
H_p = Head (J/Kg)
P = Compressor power (MW)
R = Universal gas constant 8.314 J/Kg/^oK

Compressor Fuel Requirements

For determination of fuel gas demand of the compressor stations, it is assumed that the compressors are driven by gas turbines, assuming efficiency of conversion of fuel gas heat into mechanical energy in the range of 30 percent.

SV Stations

Sectionalizing valves have been considered as per requirement of ASME code, which is specified as shown in Table 8.6:

Class location	SV Spacing
Predominantly Class 1 location	32 km
Predominantly Class 2 location	24 km
Predominantly Class 3 location	16 km
Predominantly Class 4 location	8 km

Table:8.6 SV Station Spacing

Since, it has been assumed that for the purpose of our study, the pipeline passes mostly through class 1 location, SV spacing has been kept as 32 km.

Intermediate Pigging (IP) Stations

Intermediate Pigging (IP) stations are installed in the pipeline at regular intervals to facilitate pigging of the pipeline during commissioning as well as during operation and maintenance. IP stations also function for sectionalizing a particular section.

For our study, based on pigging methodology and latest international practice, IP stations have been considered every 200 km. The IP stations are designed for intelligent pigging and are equipped with Pig Signalers, connected with SCADA.

Terminals

Among the various terminals under pipeline system are despatch terminal, receipt terminal, tap-offs and consumer terminals. Despatch terminal is installed at the beginning of a pipeline, where the incoming gas is filtered and metered and also equipped with pig launching facility. Tap-offs are provided for branching off and sending gas to another branch of pipeline. Tap-offs are provided for incoming gas well. Tap-off terminals are generally provided with check metering facilities. Receipt and consumer terminals are located at the end of the main pipeline and facilitate transmission of gas to the consumer or to another pipeline system. Consumer terminal generally includes facilities like pig receiving, filtration, pressure reduction and custody metering facilities.

For the purpose of the current study, various terminals have been considered appropriately at various locations. The general pipeline components are shown in Exhibit 8.5.

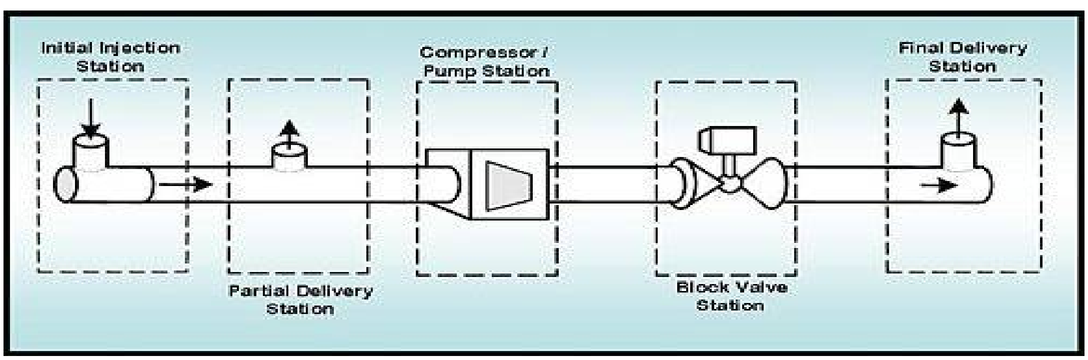


Exhibit:8.5 Pipeline Components

Other Pipeline facilities

Other major pipeline facilities include Cathodic Protection, SCADA , Telecommunication , Instrumentation facilities etc.

Impressed Current Cathodic Protection (ICCP) system has been considered for corrosion protection of pipeline. The pipe is kept as cathod, compared to the soil, with Pipe to Soil Potential (PSP) values ranging from -0.8 to -1.2 V. The system is designed a life of 30 years.

Supervisor Control and Data Acquisition (SCADA) System is designed to be installed with Remote Terminal Units (RTUs) across pipeline facilities. As per industry practice, RTUs would poll various data, namely, flow, pressure, temperature, status on established regular intervals. The system will be equipped with remote command, with local override facility. All systems, equipments, facilities are designed for compatibility for SCADA connectivity.

State of the art **telecommunication** system is designed to be installed across pipelines, through Optical Fiber Cable (OFC) communication with redundancy provided through satellite communication.

Apart from the above, a state of the art **Gas Management System** is proposed to be installed, with real time gas flow data for transmission, distribution and balancing.

8.8 SYSTEM OPTIMIZATION APPROACH

For optimization of the identified alternatives, the following steps were taken

1. Identify at lease three alternatives for a grid pipeline. For each alternative, make configuration for project details, including size, compressor spacing, power, fuel requirements and other details.

2. Make estimate of capital cost of pipeline and compressors for each alternative

3. Make estimate of operating cost of pipeline and compressors including fuel consumption cost.

4. Make cash flow sheet for 30 years with assumed debt equity ratio, capital phasing, cost of capital and depreciation and revenue from transportation.

5. Calculate internal rate of return (IRR) on pre and post tax on total project cost and on equity, assuming a revenue from given unit transportation charges.

6. Assuming internal rate of return (IRR) as 12 percent (post tax on equity), the Unit Transportation Charge, expressed in terms of US$ / MMBTU, is worked out. Transportation charge is worked out section-wise. A section

is defined as a continuous stretch after which gas flow changes, that is either increases or decreases. Transportation charge for a section is cumulated with the previous section on the principle that transportation charge is higher when the gas travels more distance.

7. Choose the alternative which gives the minimum transportation charge. This also becomes the base case for Sensitivity and further analysis.

8.9 COST ESTIMATION – CAPEX

Once the system design is carried out under different options, capital cost (CAPEX) estimation is carried out. Order of magnitude estimate of the entire project is prepared. Estimate accuracy is aimed between -10 % and + 25 %. While the estimate validity is one year from the preparation, current volatility in the world financial market may result further variation. Top down estimate is prepared on the following principles:

- 20 percent of the items provide for 80 percent of the entire estimate (Pareto Principle), hence focus is on these items which are estimated more accurately. The rest of the items are estimated on thumb rule basis.

- The above principle is also congruent upon the conceptual design philosophy, not to determine the smaller details of the system, but using approximation for the design as well for the cost estimation.

- Reference is drawn to similar projects that are the ongoing or executed, from which structure and timing are used to deliver base cost parameters to the cost model. Special focus is given to the main cost groups. e.g. fluctuating steel prices.

- While individual items may vary, overall expenditure is likely to come within the estimated accuracy on statistical level. A control calculation using the Poisson standard distribution would deliver the estimated accuracy.

- The estimate is not immune to the major volatility in the world financial market.

Methodology

Once the system design is carried out under different options, capital cost (CAPEX) estimation is carried out. For the purpose, the project is divided into major heads through **Cost Break Down** Structure (CBS).

The following CBS has been formed :

- Pipeline
  - ROU
  - Land
  - Line pipe
  - Coating
  - Internal Lining
  - SV Stations
    - Main line Valves
    - Piping materials
    - Spares
  - IP Stations
  - Laying and composite works
  - CP
  - Metering systems

- Compressors

- Engineering and project management expenses

- Contingency reserve

- Commissioning expenses

Details and Assumptions

Major assumptions are based on standard data base and reference projects. Cost data and references taken from recently executed pipeline projects in Gujarat and Maharashtra region in India, and from major projects which are half way through implementation in spanning across Gujarat, Madhya Pradesh and Delhi Region.

Pipeline route, Tap-offs

- Pipeline lengths are taken from Google Maps (Educational). While gas field sources are taken from Energy Intelligence Report, tap-offs are based on likely demands en-route. Tap-off quantities are assumed. Distances taken from the map are escalated by 2 to 5 percent, to represent and take care of surveyed length.

- Suitable assumptions are taken for available gas pressures at the sources.

- These assumptions has been clearly spelt out during analysis of the individual AGG Limbs

Right of way and crop compensation costs

The values for right of way (ROW), crop compensation and additional costs are based on reference values of an accomplished project in India.

ROW

ROW costs have been estimated on the following basis:

- ROW width is taken as 30 meters, pipeline to be laid at one side, generally at left, looking towards downstream
- ROW / purchase or servitude: 10 percent of the prevailing land cost
- Expenditure / crop compensation: on the standing crop, trees
- Total ROW cost assumed at: US$25000 / km

Permanent land for SV / IP stations

- Area requirement for SV and IP stations are 5,000 and 10,000 m^2 respectively.
- Value for permanent land is taken from accomplished similar pipeline projects in India
- Specific rates has been considered as US$ 5 / m^2 , reference taken from executed projects in India

Mainline pipes and coatings

Cost estimates of mainline pipe are considered on weight basis. The steel weight is calculated from length, diameter and wall thickness of the line pipes as per API 5L:

g	=	(D-t) * t * 0.0246615 kg
g	=	steel weight in kg per m
Dm	=	diameter in mm
tm	=	wall thickness in mm

The costs of the line pipes were determined as follows:

Cpipes	=	G * Csteel
G	=	steel weight in tonne (t) for the total length of pipeline
Csteel	=	steel costs in US$/t

- Specific cost of steel is considered as US$1650 / MT

- The cost of 3-layer PE coating and internal are calculated based on per unit rate of surface area of pipe

- Surface area of steel pipes are calculated as follow :

Area (m^2) = PI x D x L, where PI = 3.14, D = pipeline diameter in m, L = length of the pipeline in m.

- The specific cost of Line pipe, external coating, internal coating combined has been considered as US$ 30 / m2

SV / IP stations

- Cost of SV / IP stations has been calculated based on the costs of major materials, viz., Full Bore valves of required sizes and numbers and by-pass valves, and assuming factor based percent for the other materials. Estimates have been done with reference to the executed projects.

- On statistical level, it is expected that the projects would be executed within the estimated cost, with significance level of 10 percent.

Transportation Cost

The costs hereunder calculated are from the pipe mill to the respective construction sites in the 3 countries. Additional transportation costs or surcharges for long distances or difficulties (site accessibility) and unloading & reloading will meet extra charges. In the base case the cost of transportation has been estimated as follows:

Transportation	in US$ / t
Other material costs	in LS US$

The last item covers material cost including its transportation to the construction site (contractors site yard), which is usually allocated to the manufacturer.

For our study purpose, transportation cost of line pipe is included in Coating CBS and for other material in the material costs themselves.

Pipeline Construction Cost

Pipeline construction costs are calculated by defining a basic unit price per linear meter, applicable for normal and good pipe laying conditions without crossings and other special construction works.

Complicating influence of special soil conditions tend to slow down the construction progress and increase the necessary labor and equipment input, consequently resulting in increased specific construction costs. This is to be considered during the calculations, by applying a specific multiplication factor to the basic unit price, wherever applicable. This multiplication factor accounts for the additional work and its relevant cost increase for the particular area (e.g. at areas with high water tables, restricted accessibility of working strip, bad soil conditions like rock or boulders, etc.).

The general approach for this is to classify the pipeline route into three classes according to the level of difficulties encountered according to the criteria:

- Longitudinal Slope
- Side Slope
- General Soil Conditions
- Site Accessibility
- Groundwater Conditions

For each class, an appropriate evaluation factor will be developed utilizing the know-how and experience gained from numerous pervious projects.

This factor would consider the additional costs compared to normal laying conditions and would provide, in combination with the physical length, the weighted length of the respective section.

The weighted length is finally multiplied by the basic unit price per linear meter, resulting in the anticipated cost in accordance with the actual soil conditions on site. The procedure is described in detail below.

Additional costs for major crossings with water ways or other infrastructure are calculated separately by estimating the actual costs and adding to the above mentioned linear meter costs.

Basic unit price for pipeline construction:

Laying costs single line	8 US$ / inch / m
Laying costs dual line	12 US$ / inch / m

The following unit price was assumed for major river crossings:

Unit price for major river crossings single line	Included in above rate
Unit price for major river crossings dual line	Included in above rate

The values used for this estimation correspond to actual costs from previous and comparable projects, and relate to earth works and pipe-laying operations in normal, flat, dry and easily accessible terrain with a normal construction speed.

The prices cover all works and services necessary for pipeline construction, including:

- Site access, clearing, grading
- Trench excavation, pipe stringing
- Performance of all welding works, non-destructive testing of welds, coating of seams
- Bedding, pipe lowering, back filling
- Pressure tests
- Reinstatement of working strip
- Information logging, quality control, etc.

The evaluation factors for classification of the pipeline route according to the actual conditions were defined as follows:

Longitudinal Slope

Class 1 flat, level inclination up to 8°
Class 2 inclinations between 8° and 18°, fit for trucks
Class 3 inclinations between 18° and 30°, fit only for tracked vehicles

Side Slope

Class 1	level to flat, up to 7° lateral incline
Class 2	moderate lateral incline of 7° to 18°, extra excavation necessary
Class 3	steep lateral incline of 7° to 18° requiring special measures

General Soil conditions light

Class 1	loose rocks or stones - excavation possible with a normal (light) excavator
Class 2	coarse or compacted loose rock or stone, weather beaten solid rock, loosening work required - excavation possible by heavy-duty excavator
Class 3	blasting rock, salt marsh region

Site Accessibility

Class 1	easily accessible, valley site with existing approach roads
Class 2	accessible via detours, gently slope location
Class 3	accessible only with difficulty, high mountains, location on steep slope

Groundwater Conditions

Class 1	dry, without drainage
Class 2	wet, simple means for water drainage
Class 3	marsh, swamp, groundwater on site surface, difficult and extensive water drainage

Using the evaluation classes, sections of the proposed route where conditions are predominant as specified, are subsequently multiplied by the evaluation factors as shown in Table 8.7.

	Longitudinal slope	Side slope	General soil conditions	Site accessibility	Groundwater conditions
Class 1	1	1	1	1	1
Class 2	1.4	1.5	1.5	1.4	1.2
Class 3	2	3	2.5	2	2.5

Table:8.7 Evaluation Factors

This table is to be used in conjunction with a spread sheet calculating pipeline construction costs, to arrive at a construction factor to be entered into the spread sheet.

For the purpose of our study, assuming that pipelines are more than 1000 km, composite specific rate of US$8 / inch-meter for a single pipeline and US$12 / inch-meter for a twin pipeline are considered. Inch-meter of pipeline is calculated by multiplying the diameter of the pipe (in Inch) with the length (in meter).

Power Supply and Cathodic Protection System Costs

The costs for power supply and telecommunication were determined based on data from similar projects.

The costs for the Cathodic Protection System were determined based on data from similar projects.

- Cost for Cathodic protection is assumed as US$2.5 / unit surface area of pipe (m^2).

Metering Station

Metering for operation purposes and leak detection is included as part of the compressor station instrumentation. One custody metering station is required at the handing over point. The accuracy of this system is very high. In addition to the flow rate of the gas, the gas quality must also be measured. The required gas chromatographs are included in the price for the gas metering station. Since the main cost driver for metering systems is flow, and resulting sizing is based on known costs of a variety of different existing and comparable metering stations, the following rates has been considered:

Cost of metering systems: US$25000 / Flow (MMSCMD)

Communication System / SCADA

A communication and SCADA System is installed for remote control and data exchange purpose in order to operate the pipeline system. Mostly, this system consists of a fiber optic cable or directional radio link in parallel to the pipeline which connects all parts of a pipeline system. All data are monitored in the control centre for operation and communication purposes.

SCADA costs apply mainly for the stations. The SCADA portion of the pipeline derives substantially from the fiber optic cable. Specific rate considered for the above is considered as US$12000 / km

Compressor Stations

The main parameter affecting the costs of a compressor station is the installed power. The price includes

- Redundancy level of at least 30 percent
- Earth works, foundations
- Compressor house
- Piping, valves, fittings, flanges, also pigging facilities
- Construction works
- Gas turbine and compressor units (gears if required)
- Fire fighting system
- External / internal power supply
- Electrical installation
- Operational metering systems
- Streets, fencing, lighting, lightning protections

Administrative buildings or housing compounds are not included.

Cost has been estimated based on per MW of required power of a green field compressor station. Based on recent orders of compressors for an Indian project and installed compressors stations, a rate of US$2.5 million / MW of calculated power has been considered.

Engineering & Project Management Expenses

Engineering and Project Management expenses have been considered as 2 percent of the pipeline and compressor investment costs. Pipeline investment cost being high, this amount is considered to be suitable.

Contingency and commissioning expenses

While there are various approaches for providing contingency reserve in a project, for the purpose of study, a contingency provision of 1 percent has been provided.

Commissioning expenses have been considered as 1 percent of the investment cost.

Cost Saving Assessment Methodology

It has been thoroughly investigated whether, and in which project sectors, project cost savings could be achieved. This is based on anticipated project costs for construction of the gas pipeline system.

Due to the complex cost structure, project costs have been subdivided into cost groups, referred to below as 'work groups' – WG. These work groups naturally account for different percentages with respect to the overall project costs.

As indicated by the breakdown in Table 8.8, actual construction work accounts for the major share of project costs.

WG 1	Project Management / Engineering	6%
WG 2	Right of Way (ROW) Approval	3%
WG 3	Procurement	35%
WG 4	Construction	56%
Total		**100%**

Table: 8.8 Project Cost Structure

8.10 COST ESTIMATION - OPERATIONAL EXPENDITURES (OPEX)

Energy Costs

Energy costs apply for the operation of the compressor stations only, pipeline and other energy consumptions can be neglected due to their little requirements.

On account of power consumption, differences at the separate stations and during different modes of operation, the energy costs will be calculated using given gas price options. Energy cost for compressor consumptions has been considered as US$3 / MMBTU.

Maintenance and Operating Expenses (O&M)

The operating costs consist of the service costs for the pipeline and stations, as well as pure operating costs which are mainly personnel expenditure to the operation of the pipelines. This is included in the following annual rates:

a) Pipeline: 1% of the pipeline investment costs
b) Compressor Stations: 2% of the station investment costs

The above are based on thumb rule and in line with concurrent study being done for evaluation of international pipelines. These are validated by actual expenditure of installed pipelines in India

Manpower cost

Manpower costs are included in the above O&M expenses.

8.11 INVESTMENT ANALYSIS AND VIABILITY

For purpose of the study, net annual cash flow has been worked out for the project life. Flow of Capex is considered as per capital phasing. OPEX is taken on annual basis. Revenue has been calculated on transportation volume as per flow build up. This is derived from unit transportation charges multiplied by the gas transportation volume. Net annual cash flow is worked out. Internal rate of return is worked on total investment as well as equity, pre-tax as well as post tax. Initially IRR is calculated based on assumed transportation charge. Then iterations are done with target post tax equity IRR on total investment and the actual unit transportation charge is found out. Post tax IRR on Equity is also worked out.

The following data and assumptions are considered for the base case :

Project construction period	3	Years
Capital Phasing	10%	1st year
	40%	2nd year
	50%	3rd year
Project life	30	Years
Flow build up	30%	1st operating year
	50%	2nd year operating year
	80%	3rd operating year
	100%	4th year onwards
Debt	0.7	
Equity	0.3	
Interest rate	9%	
Installment	10	years
Moratorium	3	years
Depreciation- stline	9%	
Depreciation- wdv	23.50%	
Simplified tax rate	30%	
No. of Operating Days	365	days / year
Variability of TPT charge	Fixed	For entire project life
Fuel cost	3	$ /MMBTU

The investment analysis is carried out for each section under various alternatives as defined in the Optimization (Section 8.8 above). As already explained in the analysis, transportation charge is arrived at with target post tax IRR on total investment taken as 12 percent. Hence alternative with minimum transportation charge is selected as the optimum. This is also considered as base case.

8.12 SENSITIVITY ANALYSIS

Sensitivity analysis has been carried out for the base case for changes in various assumed and calculated parameters. Following variations have been considered:

1. Increase in capital expenditure by 10 %
2. Decrease in capital expenditure by 10 %
3. Increase in operating expenditure by 10 %
4. Decrease in operating expenditure by 10 %
5. Change in Debt Equity ratio from 70 : 30 to 40 : 60
6. Increase in interest rate by 1 %

7. Decrease in interest rate by 1 %
8. Increase in sales volume by 10 %
9. Decrease in sales volume by 10 %
10. Decrease in sales volume by 25 %

Results of these changes in the project IRR is plotted for the selected optimum alternative.

8.13 LIMB WISE ANALYSIS OF AGG

8.13.1 IRAN PAKISTAN INDIA PIPELINE

Iran-Pakistan-India Pipeline has been much talked about both with respect to meeting energy demand and energy security in India, and also with political perspective. The source at Iran is identified as the *Assaluyeh field*. The field has abundant gas. Based on the general conservative approach of the study, an amount of 165 MMSCMD has been considered for transportation through this pipeline. Route map of the pipeline is shown in Exhibit 8.6.

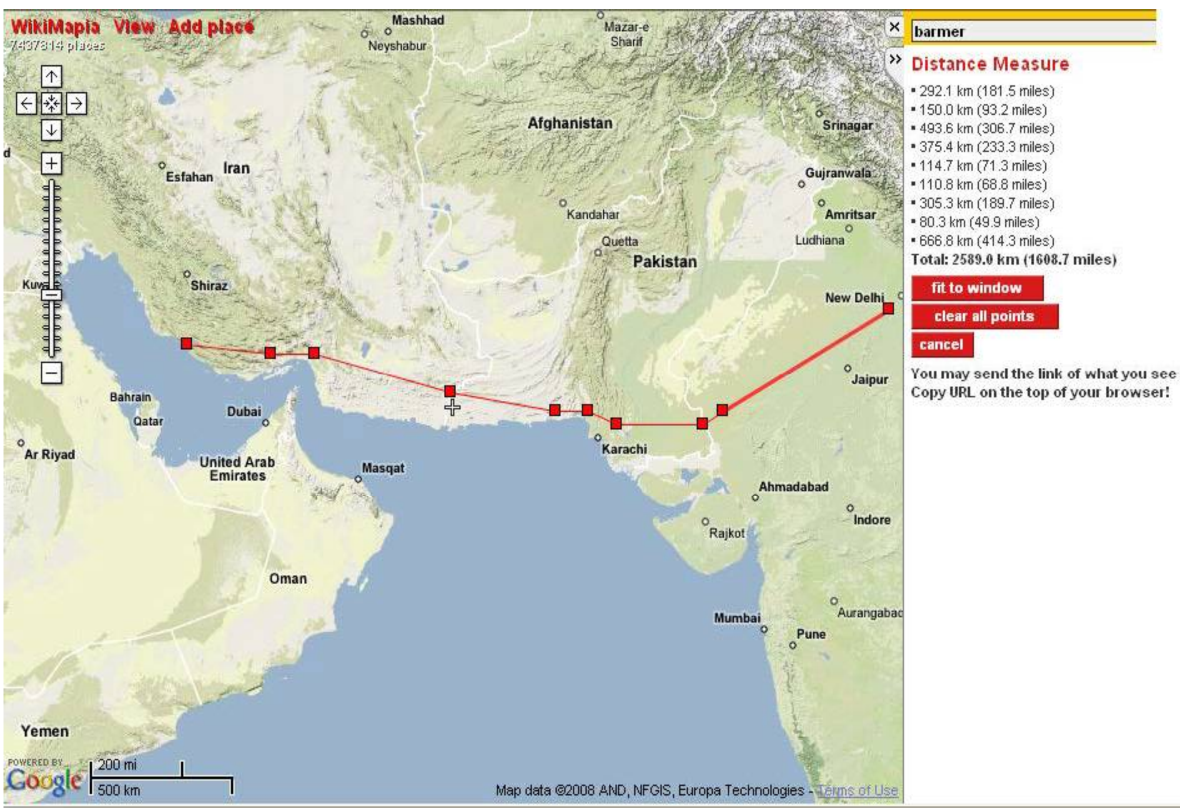


Exhibit:8.6 Iran Pakistan India Pipeline

Pipeline Route & Gas Quantity

The total distance of pipeline would be approximately 2600 km out of which approximately 950 km would be in Iran, 925 km in Pakistan and the rest of the 750 km in India. From the source, the pipeline would generally run eastwards. The initial 450 km of pipeline would encounter hilly area, while the rest of the pipeline would pass mostly through plain areas in Iran and Pakistan. Substantial portion of the pipeline is planned through a combination of hills and coastal belt in Pakistan. After entering India, the pipeline would turn north east from Jaisalmer to reach Delhi. In Rajasthan, the pipeline would encounter desert area.

Gas quantity of 165 MMSCMD is available at Assaluyeh field. The gas is considered to be available at 98 bar. A tap-off of 15 MMSCMD has been considered for Iran at chainage of approximately 800 km from the source, and a Tap-off 60 MMSCMD considered for Pakistan at approximate chainage of 1550 km from the source. Finally 90 MMSCMD reaches Delhi at a cumulative chainage of 2715 km. Efforts have been made to maintain a pressure of above 60 kg / cm2g for all tap-off, including final destination, as per general approach of the study.

Pipeline route distances, flow and tap –offs are listed in the Table 8.9.

IRAN PAKISTAN INDIA PIPELINE					
	Chainage (km)	Distance (km)	Cumulative distance-modified (km)	Flow (MMSCMD)	Flow in (+) or Flow out (-)
ASSALUYEH	0	0		165	165
POINT 2	292.1	292.1	400	165	
POINT 3	442.1	150	451	165	
TAPOFF FOR IRAN			800	165	-15
IRAN - PAK BORDER	935.7	493.6	954	150	
POINT 5	1311.1	375.4	1337	150	
POINT 6	1425.8	114.7	1454	150	
Tap-off for Pakistan (Pt 7)	1536.6	110.8	1550	150	-60
PAK - INDIA BORDER	1841.9	305.3	1879	90	
JAISALMIR	1922.2	80.3	1961	90	
DELHI	2589	666.8	2641	90	

Table:8.9 IPI - Pipeline route distances, flow and tap –offs

Summary of Findings

Three alternative line configurations were taken for analysis. First alternative was considered as 48” diameter twin pipeline, the second was twin pipeline combination of 48” and 56”, and the third was 56” diameter twin pipelines.

Line size configuration, pressure profile, compressor spacing , power and fuel consumption etc. of each section was worked out, based on calculation and approaches earlier defined in sections 8.1 to 8.12 of this chapter.

Alternative 1

SECTION	LINE SIZE (INCH)	LENGTH (KM)	CUM. LENGTH (KM)	FLOW (MMSCMD)	Pr- IN (BAR G)	Pr- OUT (BAR G)	COMPR. POWER (MW)	Fuel CONSUM (MMSCMD)
AYSS. - C1	2 X 48"	100	100	165	88	60.37		
C1 - C2	2 X 48"	150	250	165	98	59.65	125	0.96
C2 - C3	2 X 48"	150	400	165	98	59.65	127	0.97
C3 - C4	2 X 48"	150	550	165	98	59.65	127	0.97
C4 - C5	2 X 48"	150	700	165	98	59.65	127	0.97
C5 - T_IRAN	2 X 48"	100	**800**	165	98	74.65	127	0.97
SECTION TOTAL	***2 X 48"***	***800***		***165***			***633***	***4.84***
T_Iran - C6	2 X 48"	50	850	150	74.65	61.73	0	0
C6 - C7	2 X 48"	175	1025	150	98	60.77	109.22	0.84
C7-C8	2 X 48"	175	1200	150	98	60.77	115	0.88
C8-C9	2 X 48"	175	1375	150	98	60.77	115	0.88
C9- C_pak	2 X 48"	175	1550	150	98	60.77	115	0.88
SECTION TOTAL	***2 X 48"***	***750***		***150***			***454***	***3.47***
C_pak - C11	**48"x2**	**450**	2000	90	98	60.89	**66.5**	**0.51**
C11 - C12	48"	125	2125	90	98	60.69	66.22	0.51
C 12 - C13	48"	125	2250	90	98	60.69	66.72	0.51
C13 - C14	48"	125	2250	90	98	60.69	66.72	0.51
C14 - C15	48"	125	2375	90	98	60.69	66.72	0.51
C15 - DELHI	48"	125	2500	90	98	60.69	68.72	0.53
SECTION TOTAL		***625***					***401.6***	***3.07***

Table:8.10 IPI Alternative-I

Alternative II

SECTION	LINE SIZE (INCH)	LENGTH (KM)	CUM. LENGTH (KM)	FLOW (MMSCMD)	PR-IN (BAR G)	PR-OUT (BAR G)	COMPR. POWER (MW)	Fuel CONSUM. (MMSCMD)
AYSS. - C1	48" + 56"	150	150	165	88	60.57		
C1 - C2	48" + 56"	225	375	165	98	59.96	123.8	0.95
C2 - C3	48" + 56"	225	600	165	98	59.96	125.6	0.96
C3 - C4 (Iran TOP)	48" + 56"	200	800	165	98	65.29	125.6	0.96
Section total	48" + 56"	**800**		**165**			**375**	**2.87**
C4T_Iran - C5	48" + 56"	250	1050	150	98	63.31	93.24	0.71
C6 - C7	48" + 56"	250	1300	150	98	63.31	100.87	0.77
C7-C8 (PAK TOP)	48" + 56"	250	1550	150	98	63.31	101	0.77
Section total		**750**		**150**			**295**	**2.26**
C8_pak - C9	56"	225	1775	90	98	67.53	60.52	0.46
C9 - C10	56"	225	2000	90	98	67.53	51.28	0.39
C 10 - C11	56"	225	2225	90	98	67.53	51.28	0.39
C11 - C12	56"	225	2450	90	98	67.53	51.28	0.39
C12 - C13	56"	175	2625	90	98	75	51.28	0.39
Section total	**56"**	**1075**		**90**			**265.64**	**2.03**

Table:8.11 IPI Alternative-II

Alternative III

SECTION	LINE SIZE (INCH)	LENGTH (KM)	CUM. LENGTH (KM)	FLOW (MMSCMD)	PR-IN BAR G	P-OUT BAR G	COMPR. POWER (MW)	Fuel CONSUM. (MMSCMD)
AYSS. - C1	56+56	175	175	165	88	65.94		
C1 - C2	56+56	250	425	165	98	69.54	100.1	0.77
C2 - C3	56+56	250	675	165	98	69.54	85.9	0.66
C3 - Iran TOP	56"+56"	125	800	165	98	84.97	85.9	0.66
Section Total		**800**		165			**272**	**2.08**
T_Iran - C4	56" + 56"	200	1000	150	84.97	62.85		
C4 - C5	56" + 56"	300	1300	150	98	69.34	102.95	0.79
C6-C7 (PAK TOP)	56" + 56"	250	1550	150	98	74.89	79	0.6
Section Total	**56"+ 56"**	**750**		**150**			**181.7**	**1.39**
T_pak - C8	56"	80	1630	90	74.89	61.15		
C8 - C9	56"	250	1880	90	98	63.25	65.92	0.5
C 9 - C10	56"	250	2130	90	98	63.25	65.92	0.5
C10 - C11	56"	250	2380	90	98	63.25	65.92	0.5
C11 - C12	56"	245	2625	90	98	64.13	65.92	0.5
Section Total	**56"**	**1075**					**197.76**	**1.51**

Table:8.12 IPI Alternative-III

Summary of the Analysis, with details of selected size, total compression power is produced in Table 8.13.

ALTERNA-TIVE	SECTION	DISTANCE	FLOW	PIPELINE SIZE	COMPRESSION POWER	CAPEX	TRANSP TARRIF	IRR
UNITS		KM	MMSCMD	INCH	MW	MILL US$	US$ / MMBTU	%
1	1	800	165	48" dia twin line (48" x 2)	633	3839	0.4284	12
1	2	750	150	48" X 2	454	3240	0.4094	12
1	3	1075	90	48" X 2 (450 km), 48" (625 km)	401.6	3213	0.6217	12
1	**TOTAL**	**2625**			**1488.6**	**10292**	**1.4595**	
2	1	800	165	48" + 56"	375	3508	0.3672	12
2	2	750	150	48" + 56"	295	3145	0.3578	12
2	3	1075	90	56"	266	2135	0.4171	12
2	**TOTAL**	**2625**			**935.64**	**8788**	**1.1421**	
3	1	800	165	56" x 2	272	3563	0.3559	12
3	2	750	150	56" x 2	182	3153	0.3377	12
3	3	1075	90	56"	198	2534	0.4656	12
3	**TOTAL**	**2625**			**652**	**9250**	**1.1592**	

Table:8.13 IPI – Summary of Analysis

It is observed that Alternative II has the minimum transportation charge of US$1.142 / MMBTU. Hence, this is the optimum option and is recommended.

Recommended Alternative and transportation Tariff

The recommended alternative is as follow:

- **Twin pipeline of 48" and 56" diameter –** 800 km from the source (165 MMSCMD) to the tap-off point, where 15 MMSCMD is withdrawn for distribution in Iran, are required to be laid. This will have 4 Compressor stations with total required capacity of 375 MW. Total Capex is US$ 3508 Million. Transportation tariff for the entire section is US$ 0.367 / MMBTU, with Post tax IRR on equity at 12 percent.

- **Twin pipeline of 48" and 56" diameter –** 750 km from Iran tap-off point to Pakistan tap-off are to be laid. The section will carry 150 MMSCMD of gas. 60 MMSCMD, of gas will go to Pakistan after this section. This will have 3 Compressor stations with total required capacity of 295 MW.

Total Capex is US$ 3145 million. Transportation tariff for the entire section is US$ 0.725 / MMBTU, with Post tax IRR on equity at 12.01 percent.

- **A Single pipeline of 56" diameter – 1075 km** from Pakistan tap-off to Delhi is required to be laid. The section will carry 90 MMSCMD to the destination at Delhi. This will have 5 Compressor stations with total required capacity of 266 MW. Total Capex is US$ 2135 million. Transportation tariff for the entire section is US$1.14 / MMBTU; with post tax IRR on equity at 12.01 percent.

- Total capex of the recommended alternative is 8788 million US dollars.

Sensitivity Analysis

Sensitivity analysis has been carried out, with changes in various parameters and keeping the unit transportation charges, expressed in terms of US$ / MMBTU, unchanged. Results of sensitivity Analysis are shown in Table 8.14.

Sl. NO.	DESCRIPTION	PROJECT IRR	SENSITIVITY (%)	EQUITY IRR	SENSITIVITY (%)
1	BASE CASE	12		15.47	
2	Increase in capital expenditure by 10 %	10.95	-8.75	13.45	-13.06
3	Decrease in capital expenditure by 10 %	13.2	10	17.85	15.38
4	Increase in operating expenditure by 10 %	11.71	-2.42	14.93	-3.49
5	Decrease in operating expenditure by 10 %	12.27	2.25	15.99	3.36
6	Change in Debt Equity ratio from 70: 30 to 40 : 60	11.87	-1.08	13.21	-14.61
7	Increase in interest rate by 1 %	12.02	0.17	14.81	-4.27
8	Decrease in interest rate by 1 %	11.97	-0.25	16.41	6.08
9	Increase in sales volume by 10 %	13.34	11.17	18.41	19
10	Decrease in sales volume by 10 %	10.54	-12.17	12.71	-17.84
11	Decrease in sales volume by 25 %	8.14	-32.17	8.54	-32.81

Table: 8.14 IPI – Sensitivity Analysis

It is observed from the above that the Project IRR is almost proportionately sensitive to the CAPEX, but it is most sensitive to the sales volume. The IRR is less sensitive to other adverse conditions.

8.13.2 TURKMENISTAN AFGHANISTAN PAKISTAN INDIA (TAPI)

The source at Turkmenistan is identified as the *Daulatabad field*. The field has abundant gas. Based on general conservative approach of the study, an amount of 150 MMSCMD has been considered for transportation through this pipeline. Provision for connectivity to transport 50 MMSCMD of gas into TAPI from reserve rich Uzbek border field is also made through a 550 km link pipeline. This would enhance the network's flexibility. TAPI pipeline's route map is shown in Exhibit 8.7.

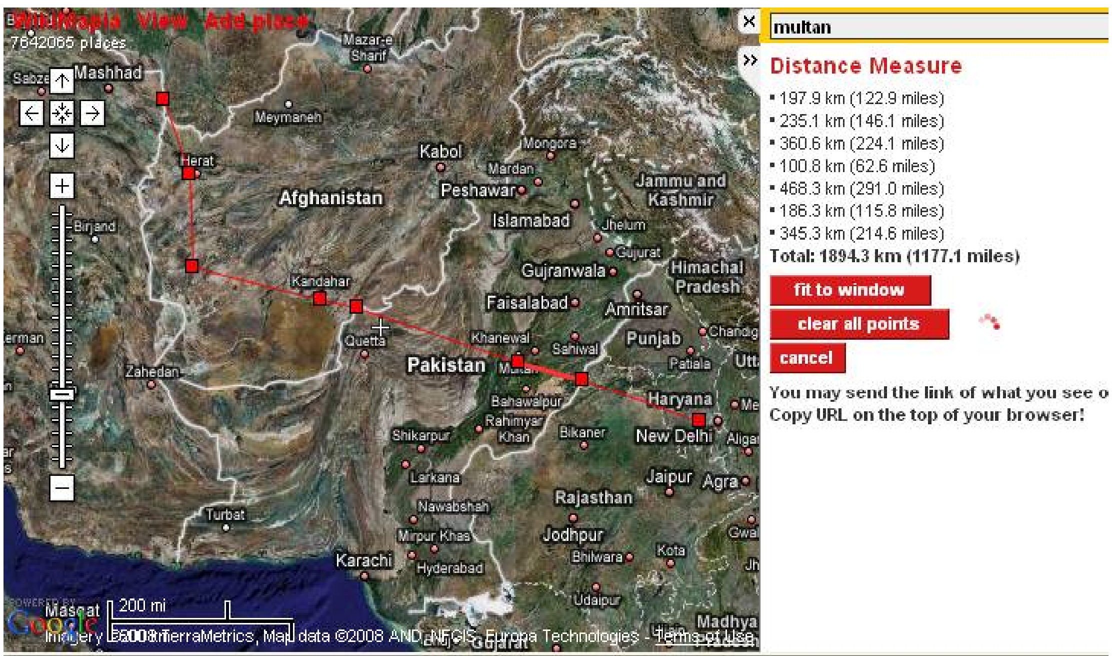


Exhibit:8.7 Turkmenistan Afghanistan Pakistan India Pipeline (TAPI)

Pipeline Route & Gas Quantity

The total pipeline distance would be approximately 1950 km. The pipeline would originate at the Daulatabad field of Turkmenistan and run approximately 100 km in Turkmenistan, about 800 km runs in Afghanistan, 670 km in Pakistan and the rest of the 400 km in India. From the source, the pipeline would generally run in the eastward direction. Substantial portion of the pipeline in Afghanistan would encounter hilly area, while the rest of the pipeline would mostly passes through plain areas in Iran and Pakistan. After entering India, the pipeline turns south east from the border to reach Delhi.

Gas quantity of 150 MMSCMD is available for transport at Daulatabad filed. The gas is considered to be available at 98 bar. A tap-off of 10 MMSCMD at Kherat and 5 MMSCMD at Kandahar has been considered for Afghanistan at chainage of approximately 200 km and 800 km respectively from the source. A tap-off 35 MMSCMD is considered for Pakistan near Multan, at approximately chainage of 1400 km from the source. Finally 100 MMSCMD would reach at Delhi at a cumulative chainage of 1950 km. Efforts have been made to maintain pressure of above 60 kg / cm2g for all tap-offs, including the final destination, as per general approach of the study.

Pipeline route distances, flow and tap-–offs are listed in the Table 8.15.

	Chainage (km)	**Distance (km)**	**Distance-modified (km)**	**Flow (MMSCMD)**	**Flow in (+), Flow out (-)**
Daulatabad	0	0		150	+150
TOP- Kherat	197.9	197.9	200	150	-10
point 2	433	235.1	442	140	
TOP - Kandahar	793.6	360.6	810	140	-5
point 4	894.4	100.8	912	135	
Multan	1362.7	468.3	1400	135	-35
point 6	1549	186.3	1580	100	
New Delhi	1894.3	345.3	1950	100	

Table:8.15 TAPI - Pipeline route distances, flow and tap –offs

Summary of Findings

Three alternative line configurations are taken for analysis. First alternative is considered as 56” diameter single pipeline, second alternative is with twin pipelines of 48” and third is combination of 48” and 56” diameter twin pipelines.

Line size configuration, pressure profile, compressor spacing, power and fuel consumption etc. of each section have been worked out based on calculation and approaches defined earlier in sections 8.1 to 8.12 of this chapter. Cost estimation is done for each section. Techno-commercial analysis is carried out for each section and optimization study carried out as spelt out in optimization approach. Configuration, pressure profile, compressor power and fuel requirement details are calculated under different alternatives.

Alternative I

SECTION	LINE SIZE (INCH)	LENGTH (KM)	CUM. LENGTH (KM)	FLOW (MMSCMD)	PR-IN (BAR G)	PR-OUT (BAR G)	COMPR. POWER (MW)	Fuel CONSUMP (MMSCMD)
DAULATABAD.C1 - C2	56"	100	100	150	98	61.85	106.5	0.81
C2 – C Kherat	56"	100	**200**	150	98	61.85	106.54	0.81
Section Total		**200**					**213**	**1.63**
CKherat-C3	56"	100	300	140	98	67.22	100	0.77
C3 - C4	56"	100	400	140	98	67.22	81	0.62
C4- C5	56"	100	500	140	98	67.22	81	0.62
C5 - C_6	56"	100	600	140	98	67.22	81	0.62
C6 - C_7	56"	100	700	140	98	67.22	81	0.62
C7 – C Kandahar	56"	110	**810**	140	98	63.33	81	0.62
Section Total		**610**					**504**	**3.85**
C_Kandahar - C8	56"	125	935	135	98	60.52	92	0.7
C8 -C9	56"	125	1060	135	98	60.52	101	0.77
C9 -C10	56"	125	1185	135	98	60.52	101	0.77
C10 -C11	56"	125	1310	135	98	60.52	101	0.77
C11 –C Multan	56"	90	**1400**	135	98	72.98	101	0.77
Section Total		590					504	
C Multan – C12	56"	50	1450	100	72.98	62.45	0	0
C12-C13	56"	200	1650	100	98	64.45	71.01	0.54
C13-C14	56"	150	1800	100	98	74.27	64.38	0.49
C-14-Arrival	56"	150	**1950**	100	98	74.27	42.19	0.32
Section Total							**178**	**1.36**

Table:8.16 TAPI Alternative-I

Alternative II

SECTION	LINE SIZE (INCH)	LENGTH (KM)	CUM. LENGTH (KM)	FLOW (MMSCMD)	PR-IN (BAR G)	PR-OUT (BAR G)	COMPR. POWER (MW)	Fuel CONSUMP. (MMSCMD)
DAULATABAD.C1 - C2	48"+48"	150	150	150	98	67.36	107	0.82
C2 – C Kherat	48"+48"	50	**200**	150	98	88.96	86	0.66
							193	**1.48**
C Kherat	48"+48"	125	325	140	88.96	64.35	0	0
C3 - C4	48"+48"	175	500	140	98	66.35	91	0.7
C4- C5	48"+48"	175	675	140	98	66.35	84	0.64
C5 - C_6	48"+48"	135	**810**	140	98	74.77	84	0.64
							258	**1.98**
C_Kandahar - C7	48"+48"	50	860	135	74.77	64.36	0	0
C7 -C8	48"+48"	200	1060	135	98	63.61	89	0.68
C8 -C9	48"+48"	200	1260	135	98	63.61	90	0.69
C9 - C Multan	48"+48"	140	**1400**	135	98	75.59	90	0.69
							269	**2.05**
Cmultan-C11	48"+48"	100	1500	100	75.59	63.68	0	0
C11 - C12	48"+48"	350	1850	100	98	63.47	67.61	0.52
C9-Carrival	48	100	**1950**	100	98	62.01	66.84	0.51
							134.45	**1.03**

Table:8.17 TAPI Alternative-II

Alternative III

SECTION	LINE SIZE (INCH)	LENGTH (KM)	CUM. LENGTH (KM)	FLOW (MMSCMD)	PR-IN (BAR G)	PR-OUT (BAR G)	COMPR. POWER (MW)	Fuel CONSUMP (MMSCMD)
DAULATABAD.C1 – C Kherat	48"+56"	200	**200**	150	98	71.61	107	0.82
							107	**0.82**
C Kherat- C2	48"+56"	60	260	140	71.61	62.35	0	0
C2 - C3	48"+56"	300	560	140	98	60.79	97	0.75
C3 -C4	48"+56"	250	**810**	140	98	68.41	104	0.8
							202	**1.54**
C_Kandahar - C5	48"+56"	300	1110	135	98	63.88	74	0.56
C5 -C6	48"+56"	290	**1400**	135	98	65.31	89	0.68
							162	**1.24**
C6multan-Carrival	48"+56"	550	**1950**	100	98	61.64	62	0.47
							62	**0.47**
C6multan- C7	56	200	1600	100	98	64.45	62	0.47
C7 - C8	56	200	1800	100	98	64.45	65.45	0.5
C8 - NEW DELHI	56	150	1950	100	98	74.27	65.45	0.5
							192.9	**1.48**

Table:8.18 TAPI Alternative-III

Summary of the Analysis, with details of selected size, total compression power is produced in Table 8.19.

ALTERNATIVE	SECTION	DISTANCE	FLOW	PIPELINE SIZE	COMPRESSION POWER	CAPEX	TRANSP TARRIF	IRR
UNITS		KM	MMSCMD	INCH	MW	MILL US$	US$ / MMBTU	%
1	1	200	150	56	107	661	0.081	12.03
1	2	610	140	56	504	2481	0.317	11.99
1	3	590	135	56	495	2418	0.347	12
1	4	550	100	56	178	2167	0.3591	12.02
1	TOTAL	1950			**1284**	**7727**	**1.1041**	
2	1	200	150	48 + 48	86	774	0.089	12.04
2	2	610	140	48 + 48	258	2352	0.2848	12
2	3	590	135	48 + 48	269	2323	0.2992	12.02
2	4	550	100	48+48 (450 KM), 48 (100)	134	1739	0.2873	12
2	TOTAL	1950			**747.45**	**7188**	**0.9603**	
3	1	200	150	48 +56	0	632	0.0622	11.99
3	2	610	140	48+56	202	2456	0.2917	12.01
3	3	590	135	48+56	162	2285	0.2772	12.01
3	4	550	100	48+56	62	1883	0.2923	12.01
3	4a	550	100	56	193	1553	0.274	12
3	TOTAL	1950			**619**	**6926**	**0.9051**	

Table 8.19 TAPI – Summary of Analysis

It is observed that the Alternative III has the minimum transportation charge of US$0.9052 / MMBTU. Hence, this is the optimum option and is selected.

Recommended Alternative and Transportation Tariff

The recommended alternative is as follows:

- Twin pipeline of 48” and 56” diameter – 810 km from the source (150 MMSCMD) to the tap-off point at Kandahar. Gas of 10 MMSCMD and 5 MMSCMD are withdrawn for distribution in Afghanistan. This will have 3 compressor stations with total required capacity of 202 MW. Total Capex is US$ 3088 million. Transportation tariff for these two sections is US$ 0.3539 / MMBTU, on cumulative basis , with post tax IRR on equity at 12 %.

- Twin pipeline of 48” and 56” diameter – 590 km from Kandahar tap-off point to Multan tap-off in Pakistan are to be laid. The section will carry 135 MMSCMD of gas. 35 MMSCMD, of gas will go to Pakistan after this section. This will have 2 compressor stations with total required capacity of 162 MW. Total Capex is US$ 2285 million. Transportation tariff up to this section is US$ 0.6311 / MMBTU, with post tax IRR on equity at 12.01 percent.

- A single pipeline of 56" diameter – 550 km from Pakistan tap-off to Delhi is required to be laid. The section will carry 100 MMSCMD of gas to the destination at Delhi. This will have 3 compressor stations with a total required capacity of 193 MW. Total Capex is US$ 6926 million. Transportation tariff at Delhi is US$ 0.9051 / MMBTU; with post tax IRR on equity at 12.01 percent.

- Total Capex of the recommended alternative is US$ 6926 million.

Sensitivity Analysis

Sensitivity analysis has been carried out, with changing various parameters and keeping the unit transportation charges, expressed in terms of US$ / MMBTU, unchanged. Results of sensitivity Analysis are summarized in Table 8.20.

S NO.	DESCRIPTION	PROJECT IRR	SENSITIVITY (%)	EQUITY IRR	SENSITIVITY (%)
1	BASE CASE	12		15.47	
2	Increase in capital expenditure by 10 %	10.95	-8.75	13.45	-13.06
3	Decrease in capital expenditure by 10 %	13.2	10	17.85	15.38
4	Increase in operating expenditure by 10 %	11.71	-2.42	14.93	-3.49
5	Decrease in operating expenditure by 10 %	12.27	2.25	15.99	3.36
6	Change in Debt Equity ratio from 70 : 30 to 40 : 60	11.87	-1.08	13.21	-14.61
7	Increase in interest rate by 1 %	12.02	0.17	14.81	-4.27
8	Decrease in interest rate by 1 %	11.97	-0.25	16.41	6.08
9	Increase in sales volume by 10 %	13.34	11.17	18.41	19
10	Decrease in sales volume by 10 %	10.54	-12.17	12.71	-17.84
11	Decrease in sales volume by 25 %	8.14	-32.17	8.54	-32.81

Table:8.20 TAPI – Sensitivity Analysis

It is observed from the above that the Project IRR is almost proportionately sensitive to the CAPEX, but it is most sensitive to the sales volume. The IRR is less sensitive to other adverse conditions.

Analysis of Turkmenistan Link Pipeline

A provision of connectivity of transporting of 50 MMSCMD gas into TAPI from reserve rich Uzbek border field is also made through a 550 km link pipeline. This would enhance the flexibility of the network. Route map of the link pipeline is shown in Exhibit 8.8.

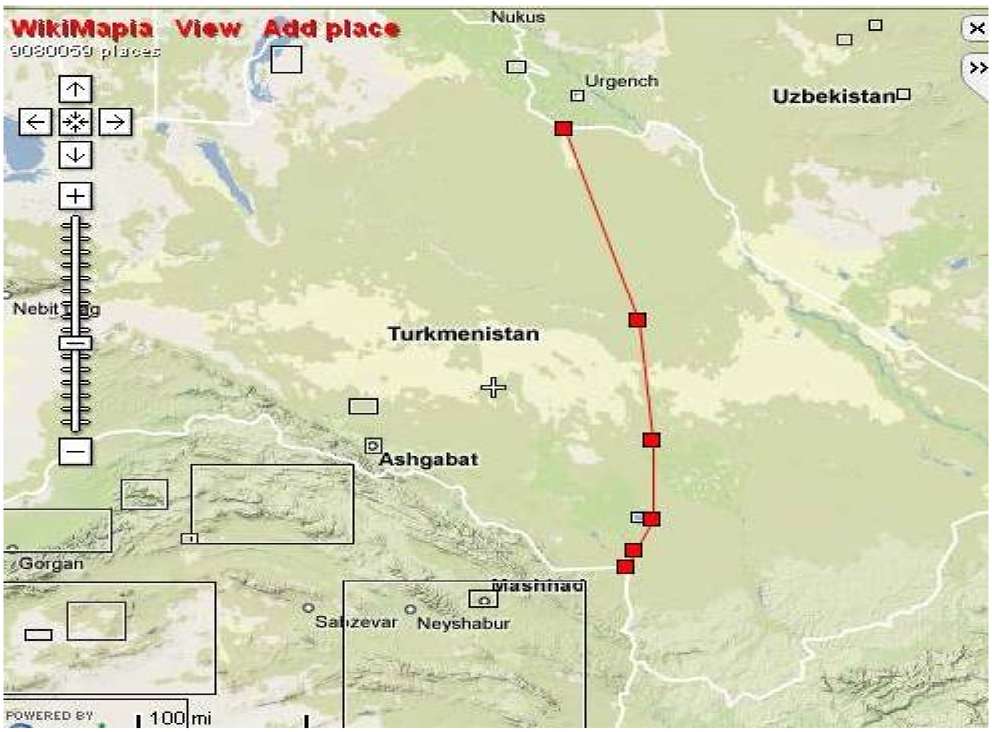


Exhibit: 8.8 Turkmenistan Link Pipeline to TAPI from Uzbek border

TURKMENISTAN LINK					
	Chainage	Distance	Distance-modified	Flow	Flow out
UZBEK BORDER FIELD	0	229.4	0	50	
POINT 4	229.4	140.1	241	50	
POINT 3	369.5	93	388	50	
POINT 2	462.5	40.2	486	50	
POINT 1	502.7	22	528	50	
DAULETABAD	524.7	0	550	50	

Table: 8.21 Link Pipeline to TAPI- Pipeline route distances, flow and tap-offs

Alternative I

SECTION	LINE SIZE (INCH)	LENGTH (KM)	CUM. LENGTH (KM)	FLOW (MMSCMD)	PR-IN (BAR G)	PR-OUT (BAR G)	COMPR. POWER (MW)	Fuel CONSUMP (MMSCMD)
UZBEK BOARDER - C1	36 +36	275	275	50	98	68.61		0
C1 - DAULETABAD	36 + 36	275	550	50	98	68.61	27.24	0.21
			550	50			27	0.21

Table: 8.22 Link Pipeline to TAPI- Alternative I

Alternative II

SECTION	LINE SIZE (INCH)	LENGTH (KM)	CUM. LENGTH (KM)	FLOW (MMSCMD)	PR-IN (BAR G)	PR-OUT (BAR G)	COMPR. POWER (MW)	Fuel CONSUMP (MMSCMD)
UZBEK BOARDER - C1	48	350	**350**	50	98	63.47		0
C1 - DAULETABAD	42	200	550	50	98	59.26	**33.3**	0.25
			550	50			33	0.25

Table: 8.23 Link Pipeline to TAPI- Alternative II

Alternative III

SECTION	LINE SIZE (INCH)	LENGTH (KM)	CUM. LENGTH (KM)	FLOW (MMSCMD)	PR-IN (BAR G)	PR-OUT (BAR G)	COMPR. POWER (MW)	Fuel CONSUMP (MMSCMD)
UZBEK BOARDER - C1	42	180	**180**	50	98	64.2		0
C1-C2	42	180	360	50	98	64.2	**32.5**	0.25
C2 – DAULETABAD	42	190	550	50	98	61.78	32.5	0.25
							65	0.5

Table: 8.24 Link Pipeline to TAPI- Alternative III

ALTERNATIVE	SECTION	DISTANCE	FLOW	PIPELINE SIZE	COMPRESSION POWER	CAPEX	TRANSP TARRIF	IRR
UNITS		KM	MMSCMD	INCH	MW	MILL US$	US$ / MMBTU	%
1	1	550	50	36+36	27	1157	0.355	12
2	1	550	50	48 x 350km, 42- 200 km	33	792	0.245	12
3	1	550	50	42	65	832	0.275	12

Table:8.25 Link Pipeline to TAPI- Summary of Analysis

8.13.3 KAZAKHSTAN UZBEKISTAN CHINA PIPELINE (KaUzChi)

Karachaganak field in North Western part of the Kazakhstan and *Caspian blocks* in the west of the country have abundant proven gas reserves (source: *Gas Intelligence Report*). Both these fields are identified as major sources of gas.

Based on the general conservative approach of the study, an amount of 100 MMSCMD and 50 MMSCMD are considered for transportation through this pipeline. Further, the route of the pipeline is selected to pass through the Uzbekistan Border in Turkmenistan, which is also has substantial proven reserves of gas. It has been considered that an amount of 50 MMSCMD would join this pipeline from this source. Together 200 MMSCMD gas would be transported from this point to Almaty in Kazakhstan, where 20 MMSCMD would be taken out. The remaining 180 MMSCMD gas would be transported to Ulumei in China, where this pipeline would join the West-East Pipeline of China.

A route map of the Pipeline is produced in Exhibit 8.9.

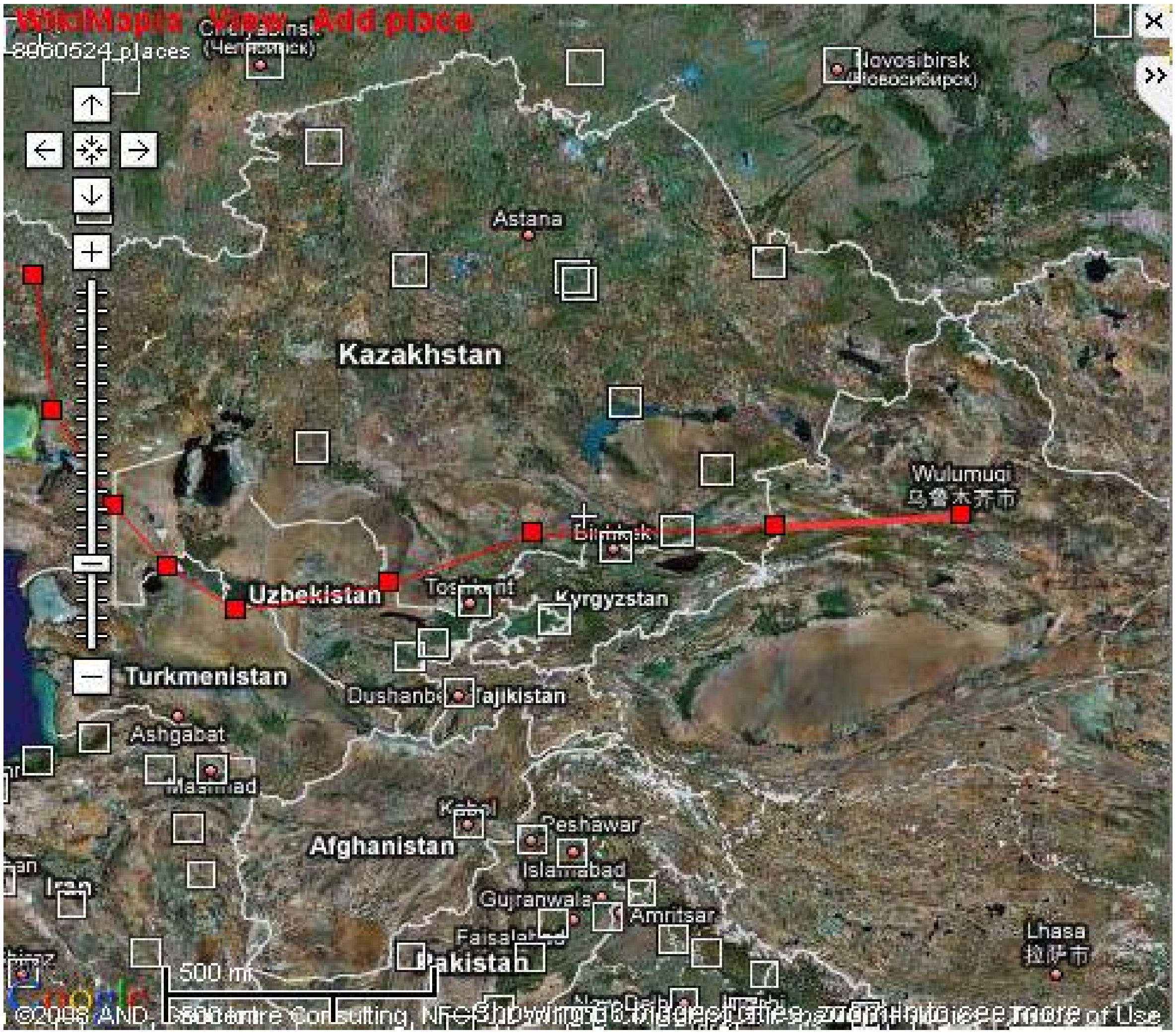


Exhibit: 8.9 Kazakhstan Uzbekistan China Pipeline (KaUzChi)

Pipeline Route & Gas quantity

The total pipeline distance is approximately 3510 km. The pipeline would originate at Karachagnak field (100 MMSCMD) in north–west Kazakhstan and thereafter, travel 400 km southwards, where the gas source of Caspian block (50 MMSCMD) will be added. The pipeline would then go in the south-east direction and reach Uzbekistan-Turkmenistan border at 1200 km. 50 MMSCMD of gas enters at this point. The pipeline would then run eastward through Uzbekistan for around 500 km and re-enter Kazakhstan. It would reach Ulumei (China) with 180 MMSCMD, through Almaty in Kazakhstan where 20 MMSCMD of gas would be taken out.

As per general approach of the study, efforts have been made to maintain a pressure of above 60 kg / cm2g for all tap-offs, including final destination.

Pipeline route distances, flow and tap-offs are listed in Table 8.26.

KaUzChi

	Chainage	**Distance**	**Distance-modified (km)**	**Flow (MMSCMD)**	**Flow in (+) / Flow Out (-)**
KARACHAGNAK	0	0		100	100
PONT 2	393.1	393.1	400	150	50
POINT 3	697.1	304	711	150	
POINT 4	940.1	243	810	150	
TURK UZBECJ BORDER	1169.8	229.7	1200	150	50
UZ KAZ BORDER	1679.9	510.1	1400	200	
POINT 7	2192.2	512.3	2236	200	
ALMATY	2580.2	388	2630	200	-20
WULMAI	3440	859.8	3509	180	

Table:8.26 KaUzChi - Pipeline route distances, flow and tap –offs

Summary of Findings

Three alternative line configurations are taken for analysis. First alternative is considered as 56” diameter twin pipelines right from the Karachangnak to the destination at Ulumei in China. Second Alternative is considered as twin Pipeline with size 48”. Under third alternative, twin pipeline, one with 48” and the other with 56” diameter is considered.

Line size configuration, pressure profile, compressor spacing, power and fuel consumption etc. of each section are worked out, based on calculation and approaches defined in earlier sections 8.1 to 8.12 of this report. Cost estimation is done for each section. Techno-commercial analysis is carried out for each section, and optimization study carried out as spelt out in optimization approach. Configuration, pressure profile, compressor power and fuel requirements details are calculated for different alternatives.

Alternative I

SECTION	LINE SIZE (INCH)	LENGTH (KM)	CUM. LENGTH (KM)	FLOW (MMSCMD)	PR-IN (BAR G)	PR-OUT (BAR G)	COMPR. POWER (MW)	Fuel CONSUMP (MMSCMD)
Karachagnak	56"+56"	400	**400**	100	88	68.39		
		400		100			**0**	**0**
C1 - C2	56"+56"	375	775	150	98	60.08	83	0.64
C2 - C3	56"+56"	375	1150	150	98	60.08	114	0.87
C3 - UZKAZ border	56"+56"	250	**1400**	150	98	74.89	114	0.87
		1000		150			**311**	**2.38**
UZKAZ BORDER border-C4	56"+56"	60	1460	200	74.8	62.48	0	0
C4-C5	56"+56"	200	1660	200	98	64.46	142	1.08
C5- C6	56"+56"	200	1860	200	98	64.46	129	0.98
C6 - C7	56"+56"	200	2060	200	98	64.46	129	0.98
C7-C8	56"+56"	200	2260	200	98	64.46	129	0.98
C8-C9	56"+56"	200	2460	200	98	64.46	129	0.98
C9- Almaty	56"+56"	172	**2632**	200	98	70.12	129	0.98
		1232		200			**785**	**6.01**
Almaty - C10	56"+56"	50	2682	180	70.1	61.13	0	0
C10- C11	56"+56"	250	2932	180	98	63.25	134.59	1.03
C 11- C12	56"+56"	250	3182	180	98	63.25	121.33	0.93
C12 - C13	56"+56"	250	3432	180	98	63.25	121.33	0.93
C13-WULMAI	56"	78	**3510**	180	98	58.01	121.33	0.93
		878		180			**499**	**3.81**

Table:8.27 KaUzChi Alternative-I

Alternative II

SECTION	LINE SIZE (INCH)	LENGTH (KM)	CUM. LENGTH (KM)	FLOW (MMSCMD)	PR-IN (BAR G)	PR-OUT (BAR G)	COMPR. Power (MW)	Fuel CONSUMP (MMSCMD)
Karachagnak-C1	48"+48"	200	200	100	88	67.11		
C1 - C2	48"+48"	200	**400**	100	98	80.11	58	0.45
		400		100			**58**	**0.45**
C2	48"+48"	75	475	150	80.11	61.67	0	0
C3 -C4	48"+48"	175	650	150	98	60.77	109	0.83
C4-C5	48"+48"	175	825	150	98	60.77	111	0.85
C4-C5	48"+48"	175	1000	150	98	60.77	111	0.85
C5- C6	48"+48"	175	1175	150	98	60.77	111	0.85
C6 - C7	48"+48"	175	1350	150	98	60.77	111	0.85
C7-UZKAZ BORDER	48"+48"	50	**1400**	150	98	88.96	111	0.85
		1000		150			**663**	**5.07**
UZKAZ BORDER-C8	48"+48"	75	1475	200	88.96	59.4	0	0
C9- C10	48"+48"	100	1575	200	98	62.02	156	1.2
C10- C11	48"+48"	100	1675	200	98	62.02	142	1.08
C11- C12	48"+48"	100	1775	200	98	62.02	142	1.08
C12- C13	48"+48"	100	1875	200	98	62.02	142	1.08
C13- C14	48"+48"	100	1975	200	98	62.02	142	1.08
C14- C15	48"+48"	100	2075	200	98	62.02	142	1.08
C15- C16	48"+48"	100	2175	200	98	62.02	142	1.08
C16- C17	48"+48"	100	2275	200	98	62.02	142	1.08
C17- C18	48"+48"	100	2375	200	98	62.02	142	1.08
C18- C19	48"+48"	100	2475	200	98	62.02	142	1.08
C19- C20	48"+48"	100	2575	200	98	62.02	142	1.08
C20 - ALMATY	48"+48"	57	**2632**	200	98	79.51	142	1.08
		1232		200			**1715**	**13.12**
ALMATY-C21	48"+48"	55	2687	180	79.51	60.25	0	0
C22-C23	48"+48"	125	2812	180	98	60.69	138	1.05
C23-C24	48"+48"	125	2937	180	98	60.69	133	1.02
C24-C25	48"+48"	125	3062	180	98	60.69	133	1.02
C25-C26	48"+48"	125	3187	180	98	60.69	133	1.02
C26-C27	48"+48"	125	3312	180	98	60.69	133	1.02
C27-C28	48"+48"	125	3437	180	98	60.69	133	1.02
C28-WULMAI	48"+48"	73	**3510**	180	98	78.7	133	1.02
		878		180			**938**	**7.18**

Table:8.28 KaUzChi Alternative-II

Alternative III

SECTION	LINE SIZE (INCH)	LENGTH (KM)	CUM. LENGTH (KM)	FLOW (MMSCMD)	PR-IN (BAR G)	PR-OUT (BAR G)	COMPR. POWER (MW)	Fuel CONSUMP (MMSCMD)
Karachagnak-C1	48"+56"	300	300	100	88	67.25	0	0
C1-C2	48"+56"	100	**400**	100	98	92.46	61.35	0.47
		300					**61.35**	**0.47**
C1-C2	48"+56"	200	600	150	92.46	63.49	0	0
C2-C3	48"+56"	250	850	150	98	63.31	100.64	0.77
C3-C4	48"+56"	250	1100	150	98	63.31	100.88	0.77
C4-UZKAZ BORDER	48"+56"	100	**1200**	150	98	85.82	100.88	0.77
		800		150			**302.4**	**2.31**
UZKAZ BORDER- C5	48"+56"	100	1300	200	85.82	58.9	0	0
C5 - C6	48"+56"	150	1450	200	98	62.3	160	1.22
C6 - C7	48"+56"	150	1600	200	98	62.3	140	1.07
C7 - C8	48"+56"	150	1750	200	98	62.3	140	1.07
C8 - C9	48"+56"	150	1900	200	98	62.3	140	1.07
C9 - C10	48"+56"	150	2050	200	98	62.3	140	1.07
C10 - C11	48"+56"	150	2200	200	98	62.3	140	1.07
C11 - ALMATY	48"+56"	150	2350	200	98	62.3	140	1.07
		150	2500	200	98	62.3	140	1.07
		130	**2630**	200	98	68.15	140	1.07
		1430		200			**1277**	**9.77**
C12- C13	48"+48"	175	2805	180	98	64.13	100	0.76
C13- C14	48"+48"	175	2980	180	98	64.13	117	0.9
C14- C15	48"+48"	175	3155	180	98	64.13	117	0.9
C15- C16	48"+48"	175	3330	180	98	64.13	117	0.9
C16-WULMAI	48"+48"	180	**3510**	180	98	62.89	117	0.9
							569	**4.35**
							1641	12.55

Table:8.29 KaUzChi Alternative-III

Summary of the Analysis, with details of selected size, total compression power is produced in Table 8.30.

ALTERNATIVE	**SECTION**	**DISTANCE**	**FLOW**	**PIPELINE SIZE**	**COMPR. POWER**	**CAPEX**	**TRANSP TARRIF**	**IRR**
UNITS		KM	MMSCMD	INCH	MW	MILL US$	US$ / MMBTU	%
1	1	400	100	56 + 56	1096	12208	1.033	12
1	2	1000	150	56 + 56				
1	3	1232	200	56 + 56				
1	4	878	180	56 + 56	500	4474	0.4322	12
1	**TOTAL**	**3510**			**1596**	**16682**	**1.4652**	
2	1	400	100	48 + 48	2436	13576	1.28	12
2	2	1000	150	48 + 48				
2	3	1232	200	48 + 48				
2	4	878	180	48 + 48	938	4850	0.5185	12
2	**TOTAL**	**3510**			**3374**	**18426**	**1.7985**	
3	1	400	100	48 +56	1641	12868	1.142	12
3	2	1000	150	48+56				
3	3	1232	200	48+56				
3	4	878	180	48+48	969	4261	0.425	12
3	**TOTAL**	**3510**			**2610**	**17129**	**1.567**	

Table 8.30 KaUzChi – Summary of Analysis

It is observed that the Alternative I has the minimum transportation charge of US$1.4652 US$/ MMBTU. Hence, this is the optimum option and is recommended.

Recommended Alternative and transportation Tariff

The recommended alternative is as follows:

- Twin pipeline of 56" diameter – 3510 km from the source (100 MMSCMD) to the destination at Ulumei in China. Apart from the sources, additional gas of 50 MMSCMD each is added at specified locations. A tap-off of 20 MMSCMD is taken out en-route at Almaty. There would be 13 compressor stations with total installed required compression capacity of 1596 MW.

- Total Capex is US$16682 million. Transportation tariff at Almaty is US$1.033 / MMBTU and at Ulumei, China is US$1.4652 / MMBTU, on cumulative basis, with post tax IRR on equity at 12 percent.

8.13.4 INDIA - BANGLADESH –MYANMAR - CHINA (IBMC) PIPELINE

The Iran-Pakistan-India (IPI) and Turkmenistan-Afghanistan-Pakistan-India (TAPI) Pipelines, would supply 90 MMSCMD and 100 MMSCMD gas to Delhi in India. 90 MMSCMD gas would be consumed in northern India. The remaining 100 MMSCMD would be taken to Haldia in West Bengal, where 50 MMSCMD would be used for consumption at Haldia and Kolkata region. The balance 50 MMSCMD would be taken further through the India-Bangladesh-Myanmar-China Pipeline.

20 MMSCMD of gas is considered to be available from *Chittagong* in Bangladesh and would be transported through this pipeline. Further on, the pipeline would pass near *Sitwe* gas field in Myanmar, where another 30 MMSCMD gas would be added. Hence, 100 MMSCMD of gas would be available to be taken to China. 10 MMSCMD and 20 MMSCMD gas would be removed en-route at Cuming and Changsa in China. Finally 70 MMSCMD gas would reach Sanghai.

It may noted here that since the source of gas is TAPI, cumulative TPT charge would be added for transportation through this pipeline.

A route map of the pipeline in two parts is produced at Exhibit 8.10. Gas flow details, Pipeline distances and tap-off locations are also tabulated.

Pipeline Route & Gas Quantity

The pipeline would run in the south-east direction from Delhi to Haldia. The route is predominantly plains including some area of the Gangetic plain. The last quarter of the Delhi-Haldia pipeline passes through Chhotanagpur Plateau. From Haldia to Chittagong, the pipeline passes mainly through coastal area. From Bangladesh to Myanmar, the pipeline passes through a combination of coastal region and hilly area. The pipeline encounters mountainous region in the Myanmar-China border region. In China, the pipeline passes mainly through plains. The total pipeline distance is approximately 5200 km.

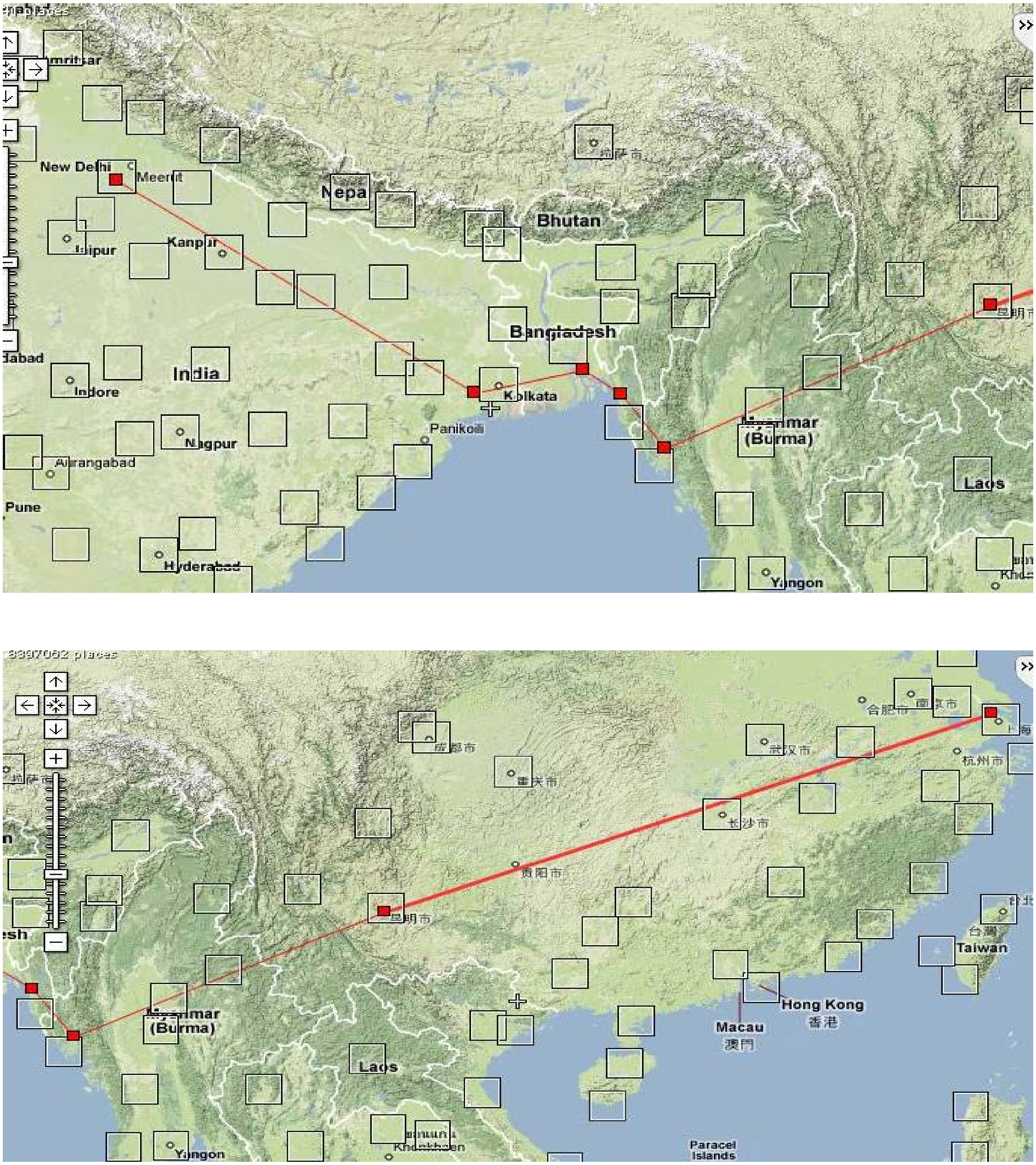


Exhibit 8.10 India Bangladesh Myanmar and Myanmar China Pipeline

As per general approach of the study, efforts have been made to maintain a pressure of above 60 kg / cm2g for all tap-offs, including the final destination. Pipeline route distances, flow and tap-offs are listed in Table 8.31:

	Chainage (km)	Distance (km)	Distance-modified (km)	Incremental distance (km)	Flow (MMSCMD)	Flow in /out
DELHI	0	0			100	
HALDIA	1254.4	1254.4	1300	1300	100	-50
POINT3	1588.8	334.4	1650	350	50	
CHITTAGONG	1727.6	138.8	1800	150	50	20
SITWE	1954.1	226.5	2050	250	70	30
PONT 6, KUMING	3038.5	1084.4	3200	1150	100	-10
POINT 7, CHANGSHA	4015.5	977	4200	1000	90	-20

Table:8.31 IBMC - Pipeline route distances, flow and tap-offs

Summary of Findings

Three alternative line configurations are taken for analysis. The first alternative is considered as 56" diameter pipeline right from Delhi to the destination at Sanghai in China, through Haldia, Chittagong and Sitwe. The second alternative is considered with size 48" throughout, while under the third alternative, the pipeline size considered would be in the combination of 48" and 56".

Line size configuration, pressure profile, compressor spacing, power and fuel consumption etc. of each section are worked out, based on calculation and approaches defined in earlier sections 8.1 to 8.12 of this report. Cost estimation is done for each section. Techno-commercial analysis is carried out for each section, and optimization study carried out as spelt out in optimization approach. Configuration, pressure profile, compressor power and fuel requirements details are calculated for different alternatives.

Alternative I

SECTION	LINE SIZE (INCH)	LENGTH (KM)	CUM. LENGTH (KM)	FLOW (MMSCMD)	PR-IN (BAR G)	PR-OUT (BAR G)	COMPR. POWER (MW)	Fuel CONSUMP (MMSCMD)
DELHI - C1	56	200	**200**	100	98	64.45		
C1 - C2	56	200	400	100	98	64.45	64.4	0.49
C2 - C3	56	200	600	100	98	64.45	64.4	0.49
C3 - C4	56	200	800	100	98	64.45	64.4	0.49
C4 - C5	56	200	1000	100	98	64.45	64.4	0.49
C5 - C6	56	200	1200	100	98	64.45	64.4	0.49
C6 - T-HALDIA	56	100	1300	100	98	82.94	64.4	0.49
India Section		**1300**					**386.4**	**2.96**
T - HALDIA - C-9	56	250	1550	50	82.94	70.31	0	0
C9-T-Chittagong	56	250	1800	50	98	87.86	26.43	0.2
INDIA - BANGLADESH		**500**		**50**			**26**	**0.2**

T- Chittagong - C-Sitwe	**56**	**250**	**2050**	**70**	**87.86**	**64.35**	**0**	**0**
C- Sitwe - C11	56	200	2250	100	98	64.45	65	0.49
C11 - C12	56	200	2450	100	98	64.45	64	0.49
C12 - C13	56	200	2650	100	98	64.45	64	0.49
C13 - C14	56	200	2850	100	98	64.45	64	0.49
C14 - C -15	56	200	3050	100	98	64.45	64	0.49
C15 - C - KUMING	56	150	3200	100	98	74.27	64	0.49
MYANMAR - KUMING		**1150**					**387**	**2.96**
C15 - C16	56	100	3300	80	74.27	60.29		0
C16 - C17	56	300	3600	80	98	64.8	51	0.39
C17 - C18	56	300	3900	80	98	64.8	51	0.39
C18 - C- CHANGSHA	56	300	4200	80	98	64.8	51	0.39
KUMING - CHANGSHA SECTION		**1000**					**152**	**1.17**
CHANGSHA -	56	350	4550	70	98	68.41	38	0.29
C10- C11	56	350	4900	70	98	68.41	38.46	0.29
C 11- C12	56	300	5200	70	98	73.37	38.46	0.29
CHANGSHA - SANGHAI SECTION		**1000**					**115**	**0.88**

Table:8.32 IBMC Alternative-I

Alternative II

SECTION	LINE SIZE (INCH)	LENGTH (KM)	CUM. LENGTH (KM)	FLOW (MMSCMD)	PR-IN (BAR G)	PR-OUT (BAR G)	COMPR. POWER (MW)	Fuel CONSUMP (MMSCMD)
DELHI - C1	48	100	**100**	100	98	62.01		
C1 - C2	48	100	200	100	98	62.01	70.61	0.54
C2 - C3	48	100	300	100	98	62.01	70.61	0.54
C3 - C4	48	100	400	100	98	62.01	70.61	0.54
C4 - C5	48	100	500	100	98	62.01	70.61	0.54
C5 - C6	48	100	600	100	98	62.01	70.61	0.54
C5 - C7	48	100	700	100	98	62.01	70.61	0.54
C5 - C8	48	100	800	100	98	62.01	70.61	0.54
C5 - C9	48	100	900	100	98	62.01	70.61	0.54
C5 - C10	48	100	1000	100	98	62.01	70.61	0.54
C5 - C11	48	100	1100	100	98	62.01	70.61	0.54
C5 - C12	48	100	1200	100	98	62.01	70.61	0.54
C12 - C-HALDIA	48	100	1300	100	98	62.01	70.61	0.54
India Section		**1300**					**847.34**	**6.48**

C - HALDIA - C-14	48	300	1600	50	98	69.46	37.47	0.29
C14 -T-Chittagong	48	200	1800	50	98	80.11	27.61	0.21
INDIA - BANGLADESH		**500**		**50**			**65.08**	**0.5**
T- Chittagong - C15	48	**50**	1850	70	80.11	69.86	0	0
C15 - C- SITWE	48	**200**	2050	70	98	60.49	35.71	0.27
BANGLA - MYANMAR		**250**		**70**			**35.71**	**0.27**
C- Sitwe - C17	48	100	2150	100	98	62.01	74.78	0.57
C17 - C18	48	100	2250	100	98	62.01	70.61	0.54
C17 - C19	48	100	2350	100	98	62.01	70.61	0.54
C17 - C20	48	100	2450	100	98	62.01	70.61	0.54
C17 - C21	48	100	2550	100	98	62.01	70.61	0.54
C17 - C22	48	100	2650	100	98	62.01	70.61	0.54
C17 - C23	48	100	2750	100	98	62.01	70.61	0.54
C17 - C24	48	100	2850	100	98	62.01	70.61	0.54
C17 - C25	48	100	2950	100	98	62.01	70.61	0.54
C17 - C26	48	100	3050	100	98	62.01	70.61	0.54
C17 - C27	48	100	3150	100	98	62.01	70.61	0.54
C27 - T_KUMING	48	50	3200	100	98	82	70.61	0.54
MYANMAR - KUMING		**1150**					**710**	**5.43**
T_KUMING - C28	48	50	3250	80	82	69.04	0	0
C28 - C29	48	150	3400	80	98	62.39	42.41	0.32
C28 - C30	48	150	3550	80	98	62.39	55.7	0.43
C28 - C31	48	150	3700	80	98	62.39	56.7	0.43
C28 - C32	48	125	3825	80	98	69.6	57.7	0.44
C28 - C33	48	125	3950	80	98	69.6	41.79	0.32
C28 - C34	48	125	4075	80	98	69.6	41.79	0.32
C34 - C-CHANGSHA	48	125	4200	80	98	69.6	41.79	0.32
KUMING - CHANGSHA SECTION		**1000**					**338**	**2.58**
C-CHANGSHA - C36	48	200	4400	70	98	60.49	36.13	0.28
C36 - C37	48	200	4600		98	60.49	52.27	0.4
C36 - C38	48	200	4800		98	60.49	52.27	0.4
C36 - C39	48	200	5000		98	60.49	52.27	0.4
C36 - C40	48	200	5200		98	60.49	52.27	0.4
CHANGSHA - SANGHAI SECTION		**1000**					**245**	**1.88**

Table:8.33 IBMC Alternative-II

Alternative III

SECTION	LINE SIZE (INCH)	LENGTH (KM)	CUM. LENGTH (KM)	FLOW (MMSCMD)	PR-IN (BAR G)	PR-OUT (BAR G)	COMPR. POWER (MW)	Fuel CONSUMP (MMSCMD)
DELHI - C1	56	200	**200**	100	98	64.45		
C1 - C2	56	200	400	100	98	64.45	64.4	0.49
C2 - C3	56	200	600	100	98	64.45	64.4	0.49
C3 - C4	56	200	800	100	98	64.45	64.4	0.49
C4 - C5	56	200	1000	100	98	64.45	64.4	0.49
C5 - C6	56	200	1200	100	98	64.45	64.4	0.49
C6 - T-HALDIA	56	100	1300	100	98	82.94	64.4	0.49
India Section		**1300**					**386.4**	**2.96**
T - HALDIA - C-9	48	150	1450	50	82.94	66.53	0	0
C9 - C-Chittagong	48	350	1800	50	98	63.47	33.42	0.26
INDIA – BANGLADESH		**500**		**50**			**33**	**0.26**
C- Chittagong - C11	48	**150**	1950	70	98	71.73	48.43	0.37
C11 - T - SITWE	48	**100**	2050	70	98	81.43	34.02	0.26
BANGLA - MYANMAR							**82.45**	**0.63**
C- Sitwe - C11	56	100	2150	100	81.43	61.85	0	0
C11 - C12	56	200	2350	100	98	64.45	72.04	0.55
C12 - C13	56	200	2550	100	98	64.45	64.4	0.49
C13 - C14	56	200	2750	100	98	64.45	64.4	0.49
C14 - C -15	56	200	2950	100	98	64.45	64.4	0.49
	56	200	3150	100	98	64.45	64.4	0.49
C15 - C - KUMING	56	50	3200	100	98	90.78	64.4	0.49
MYANMAR - KUMING		**1150**					**394**	**3.01**
C15 - C16	48	100	3300	80	90.78	66.23	0	0
C16 - C17	48	150	3450	80	98	62.39	47.8	0.37
C17 - C18	48	150	3600	80	98	62.39	55.72	0.43
C18 - C-CHANGSHA	48	150	3750	80	98	62.39	55.72	0.43
	48	150	3900	80	98	62.39	55.72	0.43
	48	150	4050	80	98	62.39	55.72	0.43
	48	150	4200	80	98	62.39	55.72	0.43

KUMING - CHANGSHA SECTION		**1000**					**326**	**2.5**
CHANGSHA -	48	200	4400	70	98	60.49	48.73	0.37
C10- C11	48	200	4600	70	98	60.49	52.369	0.4
	48	200	4800	70	98	60.49	52.369	0.4
		200	5000	70	98	60.49	52.369	0.4
		200	5200	70	98	60.49	52.369	0.4
CHANGSHA - SANGHAI SECTION		**1000**					**258**	**1.97**

Table:8.34 IBMC Alternative-III

Summary of the Analysis, with details of selected size, total compression power is produced in Table 8.35.

ALTER NATIVE	SECTION	LENGTH (KM)	FLOW (MMSCMD)	LINE SIZE, (inch)	COMPR. POWER, (MW)	CAPEX, (MILL. US$)	TRANSP. TARIFF, ($/MMBTU)	IRR (%)
1	1	1300	100	56	386.4	3240	0.482	12
1	2	500	50	56	26.43	939	0.258	12
1	3	250	70	56	0	448	0.0857	11.98
1	4	1150	100	56	387	2973	0.453	12
1	5	1000	80	56	152	2148	0.386	12.01
1	6	1000	70	56	115	2060	0.417	12.01
1		5200			1066.83	11808	**2.0817**	
2	1	1300	100	48	847.34	3694	0.618	12.01
2	2	500	50	48	65.08	805	0.236	11.99
2	3	250	70	48	35.71	412	0.08757	12.02
2	4	1150	100	48	710	3174	0.53046	12.01
2	5	1000	80	48	338	2098	0.414	11.99
2	6	1000	70	48	245	1878	0.411	12.01
2		5200			2241.13	12061	**2.29703**	
3	1	1300	100	56	386.4	3240	0.482	12
3	2	500	50	48	33.42	730	0.206	12
3	3	250	70	48	82.45	522	0.11781	12.02
3	4	1150	100	56	394	2989	0.457	12.01
3	5	1000	80	48	326	2070	0.407	12.01
3	6	1000	70	48	258	1909	0.41958	12.01
3		5200			1480.27	11460	**2.08939**	

Table 8.35 IBMC – Summary of Analysis

It is observed that Alternative I has the minimum transportation charge of US$2.082 US$/ MMBTU. Hence, this is the optimum option and is recommended.

Recommended Alternative and transportation Tariff

The selected alternative is as follows:

- A single pipeline of 56" diameter – 5200 km from the source to the destination at Sanghai in China, with required compression capacity of 1067 MW. 100 MMSCMD gas would be taken from AGG at Delhi, 50 MMSCMD gas will be taken out at Haldia for use in the eastern region of India, additional 20 MMSCMD will be added at Chittagong and further 30 MMSCMD will be added at Sitwe for carrying onward to China. 20 and 10 MMSCMD respectively taken out en-route in China.

- Total Capex is US$11808 million. Transportation tariff at Haldia (India) is US$0.482 / MMBTU and at Sanghai is US$2.0817 / MMBTU, on cumulative basis , with post tax IRR on equity at 12 percent.

Sensitivity Analysis

Sensitivity is same as that of IPI and TAPI grid line and is not separately worked out.

8.13.5 SUMMARY OF ANALYSIS

Summary of the Analysis of AGG grid is shown in table 8.36, giving details of size, length of the grid, total estimated Capital Cost etc.

LIMB	GAS SOURCES CONSIDERED	DESIGN GAS FLOW	TOTAL DISTANCE	PROJECT DETAILS	ESTIMATED COST
		MMSCMD	KM		MILLION US$
IRAN PAKISTAN INDIA	IRAN ASSAYULLAH FIELD	165	2625 KM (UPTO DELHI)	TWIN PIPELINE OF 48 & 56 INCH DIA FROM SOURCE TO 1550 KM AND 56" DIA X 1075 KM. COMPRESSORS - 936 MW	8788
TURKMENISTAN AFGHANISTAN PAKISTAN INDIA	DAUALATABAD FIELD IN TURKMENISTAN	150	1950 KM (UPTO DELHI)	TWIN PIPELINE OF 48 & 56 INCH DIA X 1400 KM , 56" DIA X 550 KM. COMPRESSORS - 936 MW	6926

TURKMENISTAN LINK PIPELINE	TURK - UZBEK BORDER FIELD	50	550 KM	48" - 250 KM , 42" - 200 KM WITH 1 COMP.OF 33 MW	792
KAZAKASTAN UZBEKISTAN CHINA	KAZAKISTAN: KARACHANGNAK, KASPIAN OFFSORE; TURK UZBEK BORDER	200	3500	TWIN PIPELINE OF 56" X 3500 KM, COMPRESSORS - 1600 MW	16682
INDIA BANGLADESH MYANMAR	DELHI (FROM TAPI), CHITTAGONG (BANGLA)	100	2050	56" X 2050 KM FROM DELHI TO MYANMAR AND COMPRESSORS : 413MW	4627
MYANMAR CHINA	IBM P/L AND SITWE (MYANMAR)	100	3150 KM (UPTO SANGHAI)	56" X 3150 KM, COMPRESSORS : 654 MW	7181
TOTAL			13825		44996

Table 8.36 Summary of Analysis of AGG Grid

Gas price, transportation charges and transit fees are tabulated in Table 8.37.

LIMB	GAS COST (A)	TRANSIT FEES (B)	TRANSP. CHARGES (C)	TOTAL COST (A+B+C)	IRR ON INVESTMENT	VIABILITY
	USD / MMBTU	USD / MMBTU	USD / MMBTU	USD/MMBTU	%	YES
IRAN PAKISTAN INDIA	7.8	0.25	1.14	9.19	12	YES
TURKMENISTAN AFGHANISTAN PAKISTAN INDIA	7.8	0.5	0.905	9.205	12	YES
TURKMENISTAN LINK PIPELINE		0.25	0.25		12	YES
KAZAKASTAN UZBEKISTAN CHINA	7.8	0.5	1.47	9.77	12	YES
INDIA BANGLADESH MYANMAR	7.8	0.5	1.27	9.57	12	YES
MYANMAR CHINA	7.8	0.25	2.08	10.13	12	YES

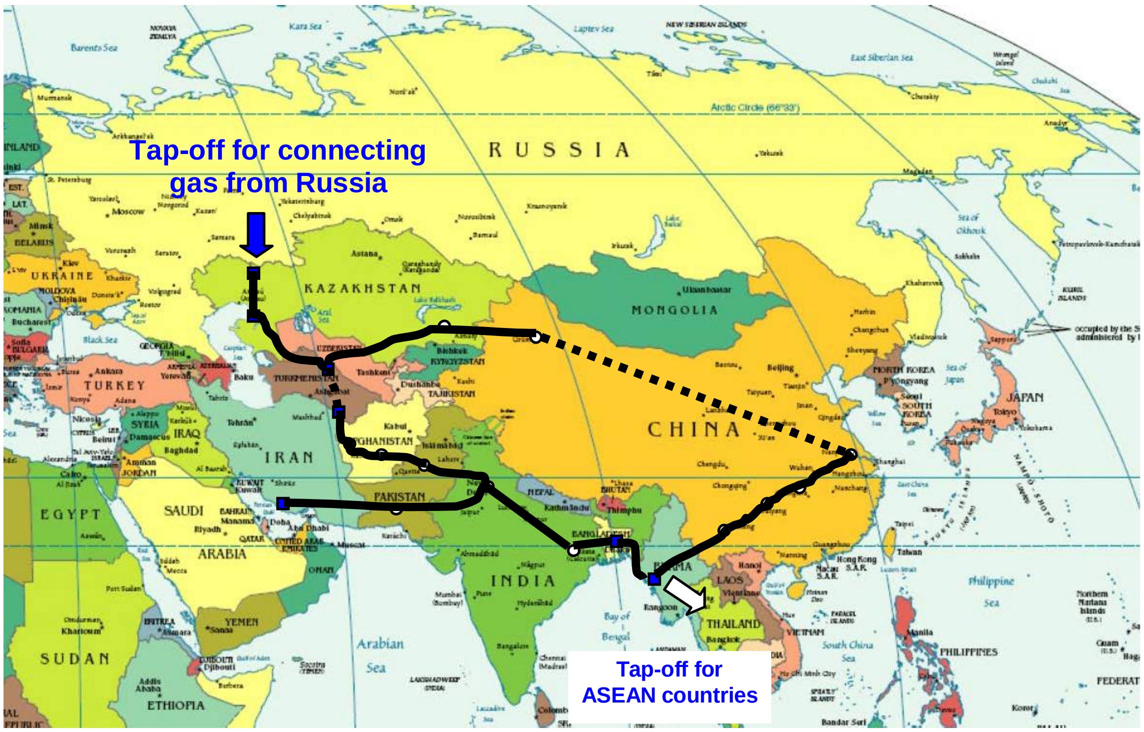
Table 8.37 Gas Pricing in Various AGG Limbs

Gas price is calculated based on the following formulae (assumed):

Gas Cost (US$/MMBTU) = 13percent of JCC (In $/barrel) where
JCC refers Japanese Crude Cocktail, taken as US$ 60 per barrel

Transit fee is taken as US$ 0.25/ MMBTU for each country in a limb, based on figures ranging from 0.15 to 0.40 prevailing in recent talks on IPI pipeline.

As per the techno-commercial feasibility study done, the proposed overall AGG Route map is shown in Exhibit 8.11. The exhibit also shows the supply/ demand centers and already existing pipelines.



LEGEND : SUPPLY CENTRES
CONSUMPTION CENTRES
EXISTING PIPELINE

Exhibit 8.11: Proposed Overall AGG Route Map

From this research it is concluded that Asian Gas Grid covering Kazakhstan, Uzbekistan, Turkmenistan, Afghanistan, Iran, Pakistan, India, Bangladesh, Myanmar, China will have the following features:

1) Optimum Length of AGG: 13825 km.
2) Diameter of Pipeline : 56”/48”
3) Gas Flow through AGG from Reserves: 565 MMSCMD
4) Cost of the Project : $ 44996 million
5) (Approximately Rs 2,25,000 cr @ 1$=Rs50)
6) Internal rate of Return of the Project: 12 %
7) Transportation Charges: approximately 1.5 US$ / MMBTU

8.14 PIPELINE ANALYSIS & DESIGN SOFTWARE (PL-ADS "GREEN CORRIDOR")

A Pipeline Analysis & Design software has been developed to facilitate carrying out the feasibility, configuration, design and other techno-commercial aspects of various limbs of the AGG .It has been named as PL-ADS "Green Corridor". The desired outputs are obtained by providing various inputs required by the software on both technical and commercial parameters,. The software CD has been separately enclosed.

A. Technical Inputs/ Outputs of the software

Inputs for Pressure Drop

1. Inlet Pressure Initial (in bars)
2. Flow Rate (in MMSCMD)
3. Base Temperature (in °C)
4. Mean Temperature (in °C)
5. Design Pressure (in bars)
6. Pipe Line Efficiency
7. Grade of Pipe
8. Corrosion Allowance
9. Thinning Allowance

Inputs for Compressor Power

1. Polytrophic Efficiency
2. Initial Temperature (in °C)
3. Discharge Pressure (in bars)
4. Compressibility (Z)

Inputs for Fuel Consumption

1. Efficiency (in %)
2. Calorific Value (in kcal/ scm)

Inputs for Mole Fraction of Gas

1. Mole Fraction of N2
2. Mole Fraction of CO2
3. Mole Fraction of H2S

List of Constants

Specific Gravity	0.68

F-Values

F1	0.72
F2	0.6
F3	0.5
F4	0.4

Ratio of Specific Heats (K)	1.4
Molecular Weight of Air (MWA)	28.7
Standard Pressure (Ps) (in kpa)	101.325
Standard Temperature (Ts) (in °C)	15

Section-wise Inputs

1. Pipe Length (in kms)
2. Diameter (D1) (in Inches)
3. Diameter (D2) (in Inches)
4. Tap Off (in MMSCMD)
5. Tap Off Type (Increase or decrease) (in MMSCMD)
6. Mech. Losses (in %)
7. Remarks

Outputs generated from technical analysis by software "Green Corridor" based on the above inputs are:

1. Outlet Pressure (in Bars)
2. Compression Ratio
3. Compressor Power (in MegaWatts)
4. Fuel Consumption (in MMSCMD)

B. Commercial Inputs/ Outputs of the software

Inputs required

Project Capital Cost		In US$ Million
Project Construction Period	3	Years
Capital Phasing	10%	1st Year
	40%	2nd Year
	50%	3rd Year
Project Life	30	Years
Flow Build Up	30%	1st Operating Year
	50%	2nd Year Operating Year
	80%	3rd Operating Year
	100%	4th Year Onwards
Debt	0.7	

Equity	0.3	
Interest Rate	9%	
Installment	10	Years
Moratorium	3	Years
Depreciation- Strt. line	9%	
Depreciation- WDV	23.50%	
Simplified Tax Rate	30%	
No. Of Operating Days	330	Days / Year
Variability Of Tpt Charge	Fixed	For Entire Project Life
Fuel Cost	3	$ /Mmbtu

Outputs generated from commercial analysis by software “Green Corridor” based on the above inputs are:

Transportation charges		US$ / MMBTU
IRR on Total Investment		%
IRR or equity		%
Debt Service Coverage ratio		

The screen snapshot of providing input for Technical analysis of IPI (for Alternative-II) is shown in Exhibit 8.12.

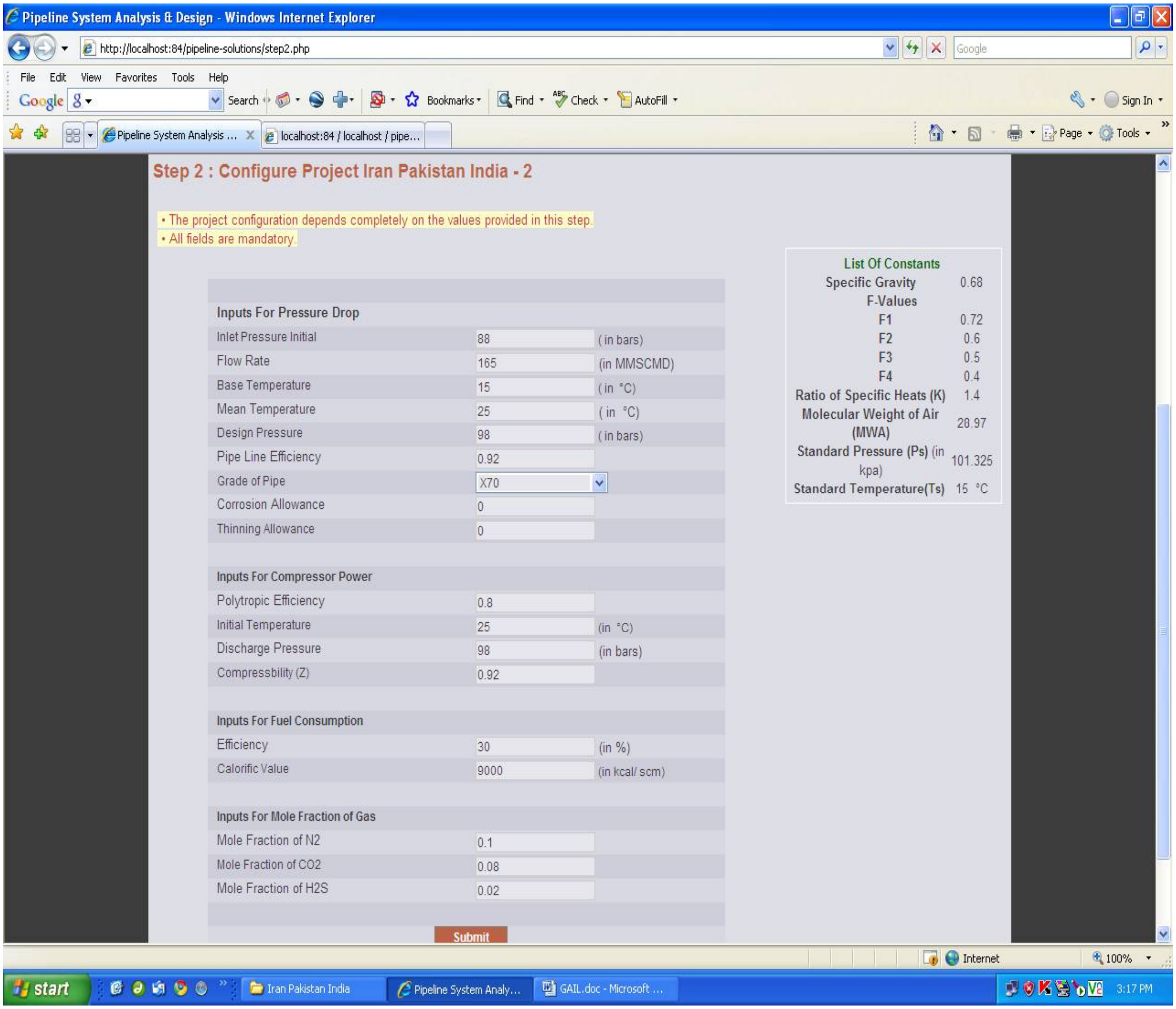
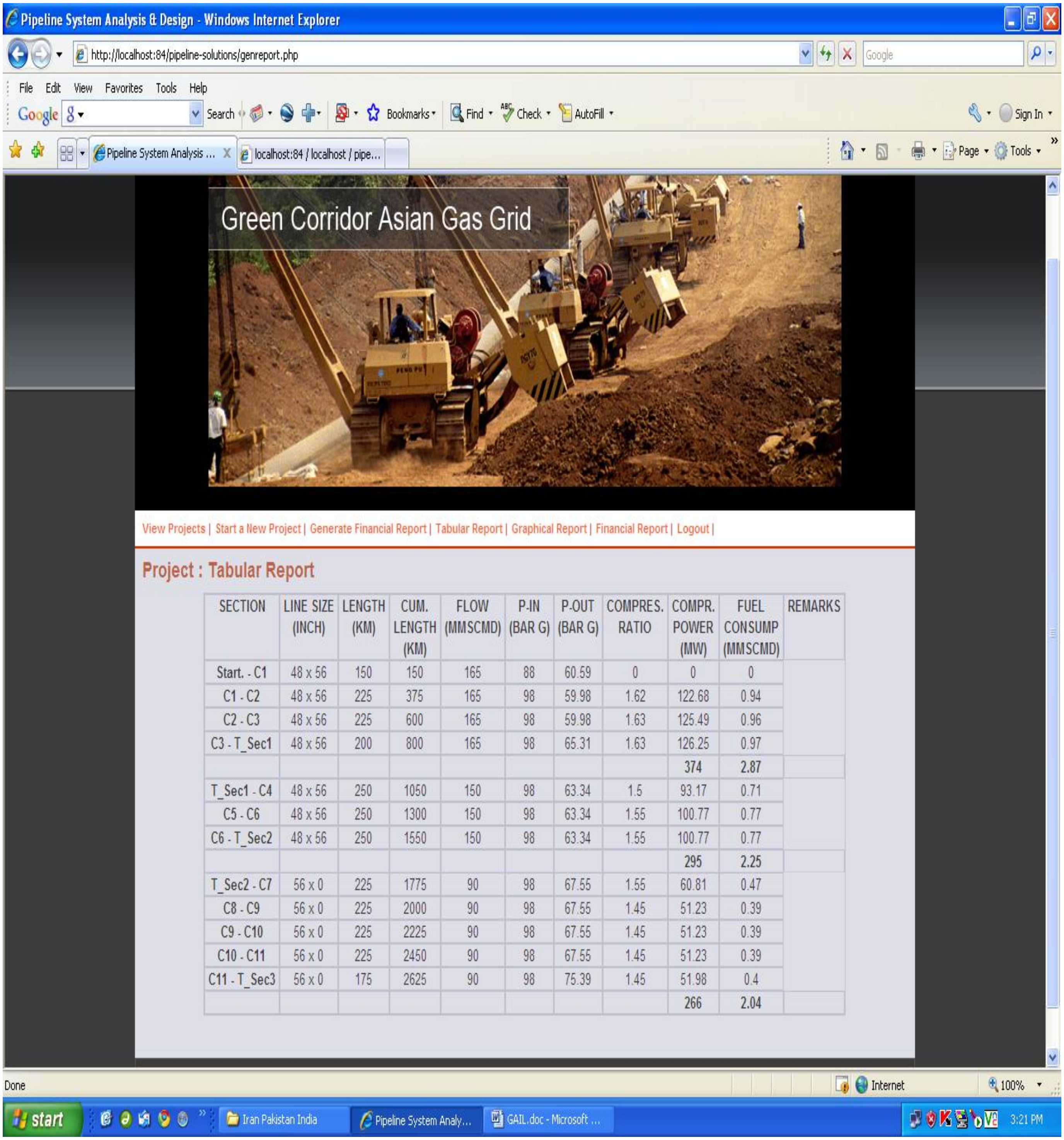


Exhibit.8.12 Software Snapshot- Technical Inputs of IPI (for Alternative-II)

The screen snapshot of output from Technical analysis of IPI (for Alternative-II) is shown in Exhibit 8.13.



SECTION	LINE SIZE (INCH)	LENGTH (KM)	CUM. LENGTH (KM)	FLOW (MMSCMD)	P-IN (BAR G)	P-OUT (BAR G)	COMPRES. RATIO	COMPR. POWER (MW)	FUEL CONSUMP (MMSCMD)	REMARKS
Start. - C1	48 x 56	150	150	165	88	60.59	0	0	0	
C1 - C2	48 x 56	225	375	165	98	59.98	1.62	122.68	0.94	
C2 - C3	48 x 56	225	600	165	98	59.98	1.63	125.49	0.96	
C3 - T_Sec1	48 x 56	200	800	165	98	65.31	1.63	126.25	0.97	
								374	2.87	
T_Sec1 - C4	48 x 56	250	1050	150	98	63.34	1.5	93.17	0.71	
C5 - C6	48 x 56	250	1300	150	98	63.34	1.55	100.77	0.77	
C6 - T_Sec2	48 x 56	250	1550	150	98	63.34	1.55	100.77	0.77	
								295	2.25	
T_Sec2 - C7	56 x 0	225	1775	90	98	67.55	1.55	60.81	0.47	
C8 - C9	56 x 0	225	2000	90	98	67.55	1.45	51.23	0.39	
C9 - C10	56 x 0	225	2225	90	98	67.55	1.45	51.23	0.39	
C10 - C11	56 x 0	225	2450	90	98	67.55	1.45	51.23	0.39	
C11 - T_Sec3	56 x 0	175	2625	90	98	75.39	1.45	51.98	0.4	
								266	2.04	

Exhibit: 8.13 Software Snapshot- Output from Technical Analysis of IPI (for Alternative-II)