ABSTRACT

This study provides a technical and economic comparison between the new Mobil methanol-to-gasoline technology under development and the commercially available Fischer-Tropsch technology for the production of motor gasoline meeting U.S. quality standards. Conceptual plant complexes, sited in Wyoming, are complete grass-roots facilities. The Lurgi dry-ash, pressure technology is used to gasify sub-bituminous strip coal. Except for the Mobil process, processes used are commercially available. Coproduction of products, namely SNG, LPG and gasoline, is practiced. Four sensitivity cases have also been developed in less detail from the two base cases.

In all areas, the Mobil technology is superior to Fischer-Tropsch: process complexity, energy usage, thermal efficiency, gasoline selectivity, gasoline quality, investment and gasoline cost. Principal advantages of the Mobil process are its selective yield of excellent quality gasoline with minimum ancillary processing. Fischer-Tropsch not only yields a spectrum of products, but the production of a gasoline meeting U.S. specifications is difficult and complex. This superiority results in about a 25% reduction in the gasoline cost.

Sensitivity study conclusions include: (1) the conversion of methanol into gasoline over the Mobil catalyst is highly efficient, (2) if SNG is a valuable product, increased gasoline yield via the reforming of SNG is uneconomical, and (3) fluid-bed operation is somewhat superior to fixed-bed operation for the Mobil methanol conversion technology.

SUMMARY

The purpose of this study is to provide a technical and economic comparison between the new Mobil methanol-to-gasoline technology and the commercially available Fischer-Tropsch technology for the production of motor gasoline meeting U.S. quality standards. Four additional sensitivity cases have also been developed in less detail from the two base cases.

The conceptual plant complexes are self-supporting, grass roots facilities located in Wyoming. The feedstock is a high volatile, sub-bituminous strip coal. Plant size is equivalent to the proposed 280 MMSCFD SNG plants. Coal gasification is by commercial Lurgi dry ash, pressure gasifiers. Except for the Mobil methanol conversion technology, all processes employed are commercially available. Plant design recognizes current environmental standards. Coproduction of all products has been generally practiced with the Lurgi gasifier methane product being marketed as SNG. No marketing restrictions have been imposed. Sufficient processing steps, however, are included to provide liquid products meeting U.S. market specifications and to produce an SNG which is interchangeable with natural gas. The study bases adopted have been guided by, but do not duplicate, those established in "Coal Gasification Commercial Concepts Gas Cost Guidelines". (Reference 1) The study scope and design bases are discussed in Sections 1 and 2.

Case definitions are briefly summarized below:

BASE CASES

CASE	I	II
Technology	Mobil Methanol Conversion	Fischer-Tropsch
Reactor Type	Fixed-Bed	Fluid-Bed
Major Products		
SNG	X	X
LPG	X	X
Gasoline	X	X
Fuels, Alcohols, etc.	-	X

SENSITIVITY CASES

CASE	I-A	I-B	I-C	II-A
Technology	Lurgi Methanol	Mobil Methanol	Mobil Methanol	Mobil Direct Route
Reactor Type	Tubular	Fixed-Bed	Fluid-Bed	Fluid-Bed
Major Products				
SNG	X	-	X	X
LPG	-	X	X	X
Gasoline	-	X	X	X
Fuels, Alcohols, etc.	-	-	-	-
Methanol	X	-	-	-

As stipulated in the contract, a fifth sensitivity case, the substitution of an advanced gasifier for the commercial Lurgi, was to be included. During its development using the Winkler pressure gasifier, it became apparent that sensitizing a different gasifier type onto a Lurgi base case is not practical. A new base case is required. Consequently, this effort is not reported.

Out of necessity, an additional sensitivity case - production of SNG only - was developed in order to obtain the SNG prices, or values, which are used in the coproduction cases for the determination of the gasoline cost. This case is briefly described in Appendix D.

The material balances for the study cases are summarized in Table 1. The superior gasoline selectivity of the Mobil methanol conversion technology is readily apparent; the 10 RVP gasoline yield is greater by about 60%. The Fischer-Tropsch technology produces a spectrum of compounds resulting in diesel and fuel oils and mixed alcohols as finished products. In addition, the Mobil technology gives a higher liquid product/SNG thermal ratio, 47/53 versus 35/65.

There are nine processing steps, common to both technologies, required for coal gasification and synthesis gas production. Nine additional steps are required for the Mobil route to achieve marketable products. The Fischer-Tropsch route, on the other hand, requires eighteen processing steps. Process descriptions and flow diagrams are included in Sections 3 and 4, in which the two base cases are discussed in detail.

Although both base cases yield gasolines meeting the target specifications, the Mobil process gasoline is of better quality, e.g., in research octane, 93 vs. 91, and in olefin content, 11 vs. 20%. In addition, the hydrotreated Lurgi gasifier naphtha with its high aromatic content, very low olefin content and good octane is an essential blending component in the F-T gasoline. The Mobil process gasoline quality, however, is not dependent upon the presence of this component.

Sensitivity Case I-A shows that the conversion of methanol to gasoline over the Mobil catalyst is highly selective and efficient. The major problem is the utilization of the additional production of low grade heat. Reforming the Lurgi gasifier methane in Sensitivity Case I-B increases the gasoline yield, about 70%, but with a severe 15% loss in the thermal efficiency. Fluid-bed operation for the Mobil methanol conversion technology, Sensitivity Case I-C, shows slightly improved gasoline yield and thermal efficiency over fixed-bed operation (Base Case I). The Mobil direct route technology, Sensitivity Case II-A, is a significant improvement over the F-T process. Gasoline upgrading is simplified and its yield is up by about 30%. Product selectivity as projected, however, is still poorer than for the Mobil methanol conversion technology. The sensitivity cases are discussed in Section 5.

Economics have been developed on both equity and utility financing. Unit costs are reported on two bases: (1) thermal basis in which each product Btu supports the plant cost and (2) multiple products basis in which plant gate values are assigned to coproducts other than gasoline and then the gasoline cost is determined. Investments and other costs have been developed specifically for the remote Wyoming site. All costs are in October, 1977 dollars. Inflation for a realistic plant start-up, e.g., in 1990, is not included. Detailed discussions of the bases are presented in the Cost and Economic Sections 6 and 7.

The economic results are summarized in Table 2. These conceptual plants are expensive, costing about 41.5 M$ per calendar FOE barrel of total product. The 155 M$ investment reduction for the Mobil Base Case over the F-T Base Case is due largely to the fewer gasoline processing units and corresponding reduced utility requirements. The conversion of methanol into motor gasoline adds from 90 to 150 MM$ to the plant investment, depending upon the reactor-type for the Mobil technology. Converting the SNG coproduct into gasoline adds about 250 MM$ to the plant investment. The Mobil direct route technology has the potential of being no more expensive than the methanol route technology.

The gasoline cost comparison between the base case technologies is:

	Gasoline Cost, ¢/gal	
	Study Basis	Gas Cost Guidelines Basis
Mobil Gasoline	60 to 100	50 to 80
F-T Gasoline	70 to 135	-

The lower costs are based on utility-type financing and pricing all coproducts at the same thermal cost in \$/MMBtu. The higher costs are based on equity financing at 12% DCF and pricing the non-gasoline coproducts according to the scenario described in Section 7. Depending upon the pricing basis, gasoline via the Mobil technology is from 10 to 25% less expensive than gasoline via Fischer-Tropsch.

If the economic bases are those given in "Gas Cost Guidelines", gasoline unit costs are about 20% lower than those developed from the study bases. Because many studies reported in the literature do not use bases reflecting actual constructing and operating conditions in remote areas, or generally use optimistic bases, we recommend the usage of the 50 to 80 ¢/gal range in these inter-study comparisons.

If SNG is a valuable, marketable product, reforming the gasifier methane is not an economical method to increase the gasoline yield. The projected fluid-bed operation has an economic advantage, up to 7¢/gal, depending upon the SNG, C_3 LPG and excess butane pricing, over fixed-bed operation for the Mobil conversion technology. The Mobil direct route technology has the potential to be economically viable. Since a high H_2/CO ratio in the synthesis gas does not appear to be critical (unlike the commercial methanol synthesis and Fischer-Tropsch processes), this technology could be an excellent partner with advanced gasifiers which generally yield synthesis gases having low H_2/CO ratios.

Detailed breakdowns of the product costs are reported in Table 3.

The sensitivity of the gasoline cost to the principal economic study bases, e.g., project life, DCF rate, interest rate, income tax, etc., and to perturbations in the investment, coal price and operating cost is discussed in Section 7.

TABLE 1
MATERIAL BALANCES

CASE	I (BASE)	I-A	I-B	I-C	II (BASE)	II-A
INPUT						
Coal, MST/SD	27.3	27.3	27.4	27.3	27.8	27.3
Water, gpm	6,300	6,200	6,800	6,000	6,600	6,600
PRODUCT						
Gasoline, B/SD	22,045	1,315(2)	37,430	23,065	13,580	17,485
SNG, MMSCF/SD	148.5	146.4	0	152.6	173.3	177.9
C_3 LPG, B/SD	1,555	-	2,665	1,790	1,107	1,675
Butanes, B/SD	2,205	-	3,800	0	146	0
Diesel Fuel, B/SD	-	-	-	-	2,307	-
Fuel Oil, B/SD	-	-	-	-	622	-
Alcohol, Mlb/SD	-	-	-	-	510	-
Methanol, B/SD	-	50,840	-	-	-	-
Fuel Oil Equivalent, B/SD(1)	45,550	47,880	36,200	45,560	44,950	45,650
OTHER						
Power, MW(e)	5.31	(6.55)	1.38	(0.08)	3.31	(1.01)
Coal Fines, MST/SD	1.2	1.6	0	1.6	0	0.3
Ammonia and Sulfur(3)						
EFFICIENCY (HHV), %	62	66	47	63	58	60

(1) All products converted to FOE barrels @ 6.0 MM Btu/B.

(2) Gasifier Naphtha

(3) Yields for each case: NH_3 = 103 ST/SD; S = 61 ST/SD

TABLE 2
ECONOMICS

CASE	I (BASE)	I-A	I-B	I-C	II (BASE)	II-A
INVESTMENT, MM$						
Onsite	762	682	874	728	826	746
Offsite	644	602	738	635	713	662
Other	326	303	374	317	348	319
TOTAL	1,732	1,587	1,986	1,680	1,887	1,727
WORKING CAPITAL, MM $	58	50	76	57	60	52
COAL COST, MM$/YR	64	64	64	64	65	64
OPERATING COST, MM$/YR	132	122	149	128	152	134
BYPRODUCT CREDIT, MM$/YR	8	9	6	9	6	6
EQUITY UNIT COST @ 12% DCF						
Thermal Product						
$/MMBTU	6.99	6.15	9.98	6.80	7.78	6.99
Gasoline, ¢/gal(1)	85	40(2)	121	83	93	85
Multiple Products						
Gasoline, ¢/gal	98	40(2)	124	93	133	106
UTILITY UNIT COST						
Thermal Product						
$/MMBTU	5.08	4.47	7.24	4.94	5.67	5.09
Gasoline, ¢/gal(1)	62	29(2)	88	60	68	62
Multiple Products						
Gasoline, ¢/gal	71	29(2)	90	67	94	76

(1) At 5.1 MMBTU/B (Cases I, I-B, I-C and II-A); 5.0 MMBTU/B (Case II)

(2) Methanol

TABLE 3
PRODUCT UNIT COST BREAKDOWN

CASE	I (BASE)	I-A	I-B	I-C	II(BASE)	II-A
EQUITY UNIT COST @ 12% DCF						
Thermal Product						
Gasoline $/MM Btu	6.99	6.15	9.98	6.80	7.78	6.99
¢/gal (2)	85	40(3)	121	83	93	85
SNG $/MM Btu	6.99	6.15	-	6.80	7.78	6.99
C_3 LPG $/MM Btu	6.99	-	9.98	6.80	7.78	6.99
Butanes $/MM Btu	6.99	-	9.98	-	7.78	-
Diesel Oil $/MM Btu	-	-	-	-	7.78	-
Hvy F.O. $/MM Btu	-	-	-	-	7.78	-
Alcohols $/MM Btu	-	-	-	-	7.78	-
Multiple Products (1)						
Gasoline $/MM Btu	8.07	6.13	10.19	7.63	11.12	8.69
¢/gal (2)	98	40(3)	124	93	133	106
SNG $/MM Btu	6.17	6.17	-	6.17	6.17	6.17
C_3 LPG $/MM Btu	6.17	-	6.17	6.17	6.17	6.17
Butanes $/MM Btu	7.77	-	9.89	-	10.82	-
Diesel Oil $/MM Btu	-	-	-	-	10.14	-
Hvy F.O. $/MM Btu	-	-	-	-	9.22	-
Alcohols $/MM Btu	-	-	-	-	11.00	-
UTILITY UNIT COST						
Thermal Product						
Gasoline $/MM Btu	5.08	4.47	7.24	4.94	5.67	5.09
¢/gal(2)	62	29(3)	88	60	68	62
SNG $/MM Btu	5.08	4.47	-	4.94	5.67	5.09
C_3 LPG $/MM Btu	5.08	-	7.24	4.94	5.67	5.09
Butanes $/MM Btu	5.08	-	7.24	-	5.67	-
Diesel Oil $/MM Btu	-	-	-	-	5.67	-
Hvy F.O. $/MM Btu	-	-	-	-	5.67	-
Alcohols $/MM Btu	-	-	-	-	5.67	-
Multiple Products (1)						
Gasoline $/MM Btu	5.84	4.43	7.40	5.51	7.38	6.29
¢/gal (2)	71	29(3)	90	67	94	76
SNG $/MM Btu	4.51	4.51	-	4.51	4.51	4.51
C_3 LPG $/MM Btu	4.51	-	4.51	4.51	4.51	4.51
Butanes $/MM Btu	5.54	-	7.10	-	7.08	-
Diesel Oil $/MM Btu	-	-	-	-	7.06	-
Hvy F.O. $/MM Btu	-	-	-	-	6.33	-
Alcohols $/MM Btu	-	-	-	-	11.00	-

(1) Discussion in Paragraph 7.1.4 on page 210.
(2) At 5.1 MM Btu/Bbl (Cases I,I-B,I-C & II-A)
At 5.0 MM Btu/Bbl (Case II)
(3) Methanol

SECTION 1
STUDY SCOPE

This study has been prepared as a joint effort by Mobil Research and Development Corporation, Lurgi Kohle und Mineraloeltechnik GmbH and American Lurgi Corporation.

1.1 BASE CASES

The primary purpose of this scoping study is to provide a technical and economic comparison between the commercial Fischer-Tropsch technology and the Mobil methanol-to-gasoline technology for the production of motor gasoline from a U.S. coal. The primary coal gasification step uses the Lurgi dry-ash, moving-bed pressure gasifier.

Base Case I is the co-production of gasoline and SNG using the Mobil methanol-to-gasoline technology currently being developed through joint funding by DOE and Mobil Research and Development Corp. The methanol is first produced from the coal derived synthesis gas.

Base Case II is the co-production of gasoline and SNG using the state-of-the-art Sasol-type Fischer-Tropsch technology. The F-T products undergo extensive upgrading to become marketable under U.S. specifications.

1.2 SENSITIVITY CASES

In addition to the above base cases, the following technical sensitivity cases have also been evaluated:

Case I-A uses the same technology and synthesis gas production as in Base Case I, except the Mobil methanol-to-gasoline technology is eliminated and methanol and SNG are the co-products.

Case I-B uses the same technology and synthesis gas production as in Base Case I except the co-production of SNG is eliminated. A reforming unit converts methane into synthesis gas which is recycled to produce additional methanol and, ultimately, additional gasoline.

Case I-C uses the same technology and synthesis gas production as in Base Case I except the Mobil methanol-to-gasoline process uses a fluid-bed reactor in place of the fixed-bed reactor used in Base Case I.

Case I-D uses the non-commercial Winkler fluid-bed pressure gasification technology in place of the commercial Lurgi gasification technology. The Winkler technology is under active development in Germany. No economics for this case, however, are reported. The Winkler gasifier, radically different from the Lurgi dry ash gasifier, requires its own base case. (See Sensitivity Section 5.)

Case II-A uses the same technology and synthesis gas production as in Base Case II except the Mobil direct route technology currently under development through joint funding by DOE and Mobil Research and Development Corp. is substituted for the Sasol-type Fischer-Tropsch.

1.3 PLANT COMPLEX DEFINITION

For each base case, a conceptual plant complex has been developed. This complex is a self-supporting, grass roots facility encompassing all process and offsite units. Except for the Mobil and Winkler technologies, all technologies used in the plant design are commercially available. Location has been assumed to be adjacent a strip coal mine in the State of Wyoming. Products manufactured are available at the plant gate for shipment to the market place.

1.4 DATA SOURCES

The process information contained in this scoping study is based on either published or licensor data. (See References.) Much of the coal gasification information was derived from the proposed commercial Western SNG plants. In fact, the conceptual plant complexes developed in this study are nearly identical to these plants up through the production of clean synthesis gas. The combining of the processes used to obtain marketable SNG and gasoline from the synthesis gas, for the most part, is based on the in-house experience of the study participants. Although Mobil is the developer of the methanol conversion technology, MRDC made special efforts to assure that an impartial philosophy was maintained by the study participants.

Coal gasification and subsequent synthesis gas purification, methanol synthesis and SNG methanation are commercially available processes of Lurgi Kohle und Mineraloeltechnik.

The information for the methanol conversion technology is derived directly from published results for the process development studies conducted by Mobil under DOE contract E(49-18)-1773 with joint DOE and Mobil funding.

The basic data for the Fischer-Tropsch technology are derived principally from published literature reference. Some MRDC estimation was required for Case II development. Sasol did not participate in the study, nor could the Department of Energy supply F-T data as originally anticipated. Consequently, MRDC cannot assertain that the F-T technology used in Base Case II is exactly the commercially demonstrated Sasol technology.

Winkler Pressure Gasifier information was supplied by Davy Powergas, Inc.

No process or design optimization back-up studies have been made. In addition, no specific laboratory work was done for this study. As needed, in-house correlations, data banks, engineering programs, cost estimating programs, etc., were used.

Investment estimates are principally derived from in-house data. Where obtainable, vendor quotes, however, have been used for the offsite units.

1.5 SCOPE OF WORK

The work performed for each of the two base cases includes:

- material balance
- utility balance
- plant thermal efficiency
- block flow diagram
- simplified process flow diagrams
- equipment lists with major equipment dimensions

Each process unit is identified and briefly described with pertinent design considerations indicated. For the hydrocarbon upgrading processes, a technology critique is also included. In addition, the design bases used for the methanol-to-gasoline and the Fischer-Tropsch units have been outlined in some detail.

For each sensitivity case, the work performed has been reduced to include only:

- overall simplified material balance
- approximate utility balance
- plant thermal efficiency
- simplified block flow diagram

Discussion is limited to the changes in the base case brought about by the sensitivity.

Scoping or budget quality investment estimates have been developed for the base cases. The investment for each process and offsite unit is identified. Estimates of the manpower, catalyst requirements and chemical usages are also provided. The investment estimates for the sensitivity cases, for the most part, have been factored from the base cases. New sensitivity unit investments, e.g., methane reformer, have been developed.

The plant complex economics have been calculated using both utility financing and private investor financing. Sensitivity of the unit cost towards coal price, SNG price, byproduct values and investment and operating cost shifts has also been developed for the base cases. An abbreviated economic analysis is presented for the sensitivity cases.

1.6 UNIT SUMMARY - BASE CASES

The plant complex is comprised of a series of inter-connected process units, utility and support facilities (offsite units) and general plant facilities (infra-structure) as defined below:

PROCESS UNITS

Unit No.	Description
	Base Case I
101	Gasification (Lurgi Coal Pressure Gasification)
102	Raw Gas Shift
103	Raw Gas Cooling
104	Shifted Gas Cooling
105	Gas Purification (Rectisol)
106	Sulphur Recovery (Stretford)
107	Gas Liquor Separation
108	Phenol Recovery (Phenosolvan)
109	Ammonia Recovery (Chemie Linz/Lurgi)
110	Methanol Synthesis (Lurgi Low Pressure Process)
111	H_2 Recovery (Pressure Swing)
112	Methanation
113	CO_2 Removal (MEA Wash)
114	SNG Drying (TEG Wash)
150	Methanol Conversion (Mobil)
151	Naphtha Hydrotreating
152	Fractionation
153	HF Alkylation
	Base Case II
201 to 209	Identical to Base Case I
210	Hydrocarbon Recovery (Heptane Wash)
211	H_2 Recovery (Pressure Swing)
212	Methanation
213	CO_2 Removal (MEA Wash)
214	SNG Drying (TEG Wash) and Compression
250	F-T Synthesis
251	Naphtha Hydrotreating
252	F-T Product Fractionation
253	F-T Product Hydrotreating
254	Hydrotreated Product Fractionation
255	Catalytic Reforming
256	C_5/C_6 Isomerization
257	Catalytic Polymerization
258	HF Alkylation
259	Poly Gasoline Hydrogenation
260	Light Ends Recovery
261	H_2 Purification
262	Alcohol Recovery

OFFSITE UNITS
(Base Cases I and II)

Unit No.	Description
121/221	Oxygen Production (Air Separation)
122/222	Boiler
123/223	Main Superheater
124/224	Superheater
125/225	Electrostatic Stackgas Precipitator
126/226	Stackgas Clean-Up
127/227	Instrument and Plant Air
128/228	Coal Handling
129/229	Ash Handling
131/231	BFW Preparation (Deaerator & Demineralizer)
132/232	CW Make-Up Preparation
133/233	CW Towers
134/234	Electric Power Generation
135/235	Waste Water Treatment (Biological)
136/236	Relief and Blow-Down Facilities
137/237	Storage
138/238	Interconnecting Piping
141/241	Refrigeration
154/270	Gasoline Blending
271	F-T Catalyst Preparation

INFRASTRUCTURE
(Base Case I and II)

Office Buildings
Cafeteria
Maintenance Shops
Warehouse
Laboratory
Fire Protection System
Electric Distribution System
Truck and Railroad Unloading/Loading Facilities
Sewers
Roads and Parking Lots
Fencing
General Lighting
Communication and Security
Site Preparation

SECTION 2
STUDY DESIGN BASES

Where applicable, the plant design bases adopted for this study are generally those established by C.F. Braun & Co. for DOE in "Coal Gasification Commercial Concepts Gas Cost Guidelines" (Reference 1). A discussion of the principal bases follows.

2.1 PLANT CAPACITY

For both base cases, the plant capacity is based upon the gasification of 1,272 Mlb/hr of DAF coal. This amount of coal produces 742 MMSCF/SD of dry, purified synthesis gas for feed to methanol synthesis (Base Case I) or feed to Fischer-Tropsch synthesis (Base Case II). For reference, this capacity is equivalent to the capacity of the large 280 MMSCF/SD commercial SNG plants under consideration for the United States and, thus, is similar to the Guidelines plant size.

In the sensitivity cases, the gasification rate and synthesis gas yield are the same as used in the base cases, except for Sensitivity Case I-D. In this sensitivity, the 10 RVP gasoline product is the same as the Base Case I.

Because of differing energy requirements, the total coal charge, however, is not the same among the various cases.

2.2 DESIGN PHILOSOPHY

The overall plant complex has been designed using multiple trains, spare equipment and intermediate storage to provide an overall onstream factor of 92 percent. (See Sub-Sections 3.7 and 4.7.)

2.3 FEEDSTOCKS

The only feedstocks to the plant complex, besides air, are mined coal and fresh water. In addition, small quantities of chemicals, solvents and catalysts are required.

2.3.1 Coal

Gasification and boiler-firing are based on a coal having the properties listed in Table 2.1. This coal is a low sulfur, Wyoming sub-bituminous coal. Its properties differ slightly from the base Montana sub-bituminous coal in the Guidelines. It is a prime feedstock for the Lurgi dry-ash, pressure gasifier.

TABLE 2.1
STUDY COAL PROPERTIES
(Wyoming Sub-Bituminous Coal)

	As Received	Dry and Ash Free (DAF)
Proximate Analysis, wt. %		
Moisture	28.0	--
Ash	5.1	--
Fixed Carbon	33.8	50.5
Volatile Matter	33.1	49.5
	100.0	100.0
Ultimate Analysis, wt. %		
C		74.45
H		5.10
O		19.25
N		0.75
S		0.45
		100.00
Calorific Value, Btu/lb		
High Heating Value (HHV)	8,509	12,720
Low Heating Value (LHV)	7,893	12,236

Fusion Properties of Ash, °F	Atmosphere: Oxidizing	Atmosphere: Reducing
Softening Point	2,335	2,335
Melting Point	2,360	2,360
Flow Point	2,440	2,430

Mineral Analysis of Ash	Wt. %
SiO_2	19.0
Al_2O_3	14.0
Fe_2O_3	6.0
MgO	7.8
CaO	36.0
Na_2O	2.7
K_2O	0.2
SO_3	7.0
BaO	0.2
TiO_2	1.0
P_2O_5	1.8
Undetermined	4.3
	100.0

2.3.2 Fresh Water

The quality of the untreated fresh water assumed is the Western location water quality established in the Guidelines. In summary, the total dissolved solids are 496 ppm and the total hardness is 232 ppm $CaCO_3$. It has been assumed that the water is available at the plant gate.

2.4 CLIMATIC CONDITIONS

Essentially, the climatic conditions established in the Guidelines have been used. In summary, they are:

Atmospheric pressure, psia	12.3
Air temperature (average), ^oF	50
Relative humidity (average), %	70
Summer wet bulb, ^oF	66
Summer dry bulb, ^oF	95

2.5 PLANT SITE CONDITIONS

No major site development, other than leveling and grubbing, has been assumed. No piling is assumed to be required.

2.6 ENVIRONMENTAL REGULATIONS

The plant complex has been designed to meet all existing local and federal environmental regulations, as of July, 1977, for liquid and gaseous effluents.

Boiler stack gas clean-up facilities for SO_2 removal are provided to reduce the SO_2 emissions to 0.2 pounds of SO_2 per million Btu of fired heat. In addition, an electrostatic precipitator is included to reduce the particulate matter to 0.1 pound per million Btu of fired heat duty.

Although the sulfur emission target is more severe than the limitation in the Gas Cost Guidelines, this specification is the design limit for the latest proposed commercial Wyoming SNG plant (Panhandle Project). (Note: When calculating the "boiler" fired duty, the main superheater duty is included and LHV is the basis.)

Sulfur emissions from the process units are reduced by treating all sulfur containing offgases in a sulfur recovery unit. The tail gas stream containing 10 ppm H_2S from this unit is incinerated in the boiler to eliminate the hydrocarbons and to convert the COS and H_2S to SO_2 for removal in the stack gas clean-up facility. Only about 6% of the sulfur in the total coal charge escapes as SO_2, amounting to about 5 T/SD of sulfur.

All aqueous liquid effluents are treated and recycled. Blowdown water is used for ash slurrying, dust control, etc..

The wet ash and solid wastes, e.g., from stack gas clean-up and water treating, are sent to the mine for disposal.

2.7 PRODUCTS

Except as discussed below, this study is based on the concept that all products are marketable. Other than quality specifications, no marketing restrictions have been imposed. Products have been credited with their highest potential market value. The major products, however, are SNG and motor gasoline. A product summary is tabulated below:

	Base Case		----Sensitivity Case----				
Product	I	II	I-A	I-B	I-C	I-D	II-A
SNG	X	X	X	-	X	-	X
Methanol	-	-	X	-	-	-	-
Gasoline	X	X	-	X	X	X	X
Propane LPG	X	X	-	X	X	X	X
Butane LPG	X	X	-	X	-	X	X
Diesel Oil	-	X	-	-	-	-	-
Heavy Fuel Oil	-	X	-	-	-	-	-
Alcohols	-	X	-	-	-	-	-
Ammonia	X	X	X	X	X	-	X
Sulfur	X	X	X	X	X	X	X
Electric Power (excess)	X	X	X	X	X	X	X
Coal Fines (excess)	X	-	X	-	X	-	X

The Lurgi gasifier produces phenols, naphtha, oil and tar which are recovered during raw gas cooling. For expediency, the phenols, oil and tar are used as boiler fuel. Although technically possible, the upgrading of these materials into saleable products would have little, if any, effect on the plant complex economics. On the other hand, the gasifier naphtha is hydrotreated for gasoline blending, principally, because this aromatic stock is needed to yield a satisfactory 10 RVP gasoline in the Fischer-Tropsch case.

The Fischer-Tropsch reaction produces a small quantity of acids. They have been neutralized with caustic as recovery is not economical (8).

Ammonia and hydrogen sulfide obtained during raw syn gas purification are recovered as anhydrous ammonia and sulfur.

2.8 PRODUCT SPECIFICATIONS

2.8.1 SNG

The SNG product has been formulated to be interchangeable with pure methane as determined by three indexes. (See Guidelines.) The first two - lifting and flash-back - relate the dynamic equilibrium between the speed of the air-gas mixture issuing from the burner and the ignition velocity of the gas for the substitute gas to that for the standard gas. For example, a burner adjusted for pure methane will exhibit flame lifting if the inerts (N_2) concentration of a substitute gas is too high, or will have flash-back problems if the SNG concentration of hydrogen, with its high ignition velocity, is too high. The third - yellow-tip - relates the amount of olefins or illuminants in the substitute gas to the amount in the standard gas.

In addition, it meets the following limitations:

Carbon monoxide	0.1 vol. %
Hydrogen sulfide	0.25 grains/100 SCF
Total sulfur	10 grains/100 SCF
Water	4 lb/MMSCF,

and is available at the plant gate @ 1,000 psig.

2.8.2 Hydrocarbon Products

The target specifications are primarily based on the 1976 Annual Book of ASTM Standards and represent industry guidance for establishing product properties between buyer and seller. Properties and comments specific to the various hydrocarbon products can be found in the discussion and tables included in Sub-Section 3.2 and 4.2.

2.8.3 Alcohols

No specifications have been established. The alcohol product has been upgraded to be essentially free of water, acids, aldehydes and ketones.

2.8.4 Byproducts

Ammonia: Agriculture grade is produced. (With a relatively small increase in costs, chemical grade ammonia could be produced by the ammonia recovery process used in the study.)

Sulfur: The product is a liquid at 99.5% purity.

Electric Power: Excess electric power is produced at 6,000 volts.

2.9 COAL BALANCE

The number of Lurgi gasifiers is based on coal sized in the range of 1/4" to 2", containing not more than 7% undersize. The minus 1/4" coal is used as boiler fuel. When crushing the study coal, it has been estimated that the coal preparation plant yields 83.5% 2" to 1/4" gasifier coal and 16.5% minus 1/4" fines. Since the study basis calls for the combustion rather than the recovery of the gasifier tar, oil and phenols, a surplus of fine coal is possible. When this occurs, the excess fines are sold in accordance with the Guidelines.

2.10 UTILITY BALANCE

The general design bases calls for in-plant power and steam generation and, if possible, no export of these items. The utility balances were developed towards this goal, but detailed utility rebalancing calculations are outside the limits of this scoping study. Thus, a small surplus of electric power is available for export in the base cases, amounting to less than 5% of the total steam and electric power required to operate the complex. In the sensitivity cases, the balance swings from purchase to surplus electric power.