1.0 EXECUTIVE SUMMARY

1.1 Background

Indirect liquefaction of coal is a process in which the carbon in the coal is consumed in a reaction with steam and oxygen to produce synthesis gas ($CO + H_2$), which, after cleaning, is reacted over suitable catalysts to yield desired hydrocarbons. The basic technology dates back to the early 20th century. Indirect processes were used in Germany to produce fuels, petrochemicals and even edible fats from coal before and during World War II.

The only significant application of fuel-oriented indirect coal conversion technology since WW II has been in the Republic of South Africa, where an abundance of poor quality coal, a dearth of petroleum resources, and a political and economic need for resource autonomy have led to the development of a coal conversion industry. This development was undertaken by SASOL (South Africa Coal, Oil and Gas Corporation, Ltd.), a quasi-government corporation formed and capitalized for that purpose. SASOL I, which began operation in 1954, supplied about 5 percent of South Africa's motor fuel needs plus other fuels and petrochemicals. SASOL II began operation this year and is four times larger. When SASOL III is completed in 1985, South Africa will have the capability of meeting about 40 percent of their liquid fuel and petrochemical needs from coal.

In the rest of the world, the 20 years following WW II was a period in which interest in coal conversion was dominated not by a desire to have coal fulfill an increasing role, but to make it environmentally suitable for continued use in its traditional role in electric power generation. These motives led to interest in R&D in magnetohydrodynamics (MHD), and in gasification and direct conversion processes which could clean and reform coal to make it an economic and environmentally acceptable boiler fuel.

The events of the 1970's have cast the role of coal in an entirely new light. The present need is not that of preserving the value of coal, but of using this abundant resource to meet a broad range of energy needs in an era of diminishing petroleum resources. To fill this role, coal must be substituted for a broad range of fuels now produced from petroleum.

The earlier judgments that direct hydrogenation or gasification were the most efficient methods of producing an environmentally acceptable boiler fuel from coal were demonstrably sound. However, the proven ability of indirect coal conversion processes to produce high quality motor fuels and petrochemical substitutes has become increasingly important, and this technology deserves a careful re-examination.

The present study first investigates the potential of a U.S. plant employing proven commercial technology as implemented in South Africa. These findings are then used as a basis for evaluating the potential of more advanced technology gasifiers and synthesis systems to improve technical and economic performance of indirect coal conversion processes. The gasifiers were selected on the basis of their advanced stage of development; all have had successful large pilot plant operation.

1.2 SASOL Technology

SASOL II employs dry ash Lurgi gasifiers of German design, and fast fluid (entrained recirculating) bed Synthol Fischer-Tropsch synthesis reactors developed by SASOL and Kellogg U.S. The Lurgi Mark IV gasifiers at SASOL II have been considerably improved because of the extensive operating experience at SASOL I. The Synthol reactors, although initially developed by Kellogg, have been redesigned by SASOL and have been considerably improved because of the extensive problems with the original design. SASOL now holds all patents on the Synthol reactor. This combination is capable of delivering clean fuels and petrochemicals with an efficiency approaching 60 percent. However, 19 percent of the carbon in the coal leaves the dry bottom Lurgi as methane. When the H_2 and CO in the synthesis gas is reacted in the Synthol units, about 25 percent of the output is methane. Additional light gases are formed when the synthesized liquids are upgraded to specification fuels. When operating at peak efficiency the dry ash Lurgi/Synthol combination yields over 50 percent of its output as Synthetic Natural Gas.* At SASOL II, these gases are reformed by partial

*The MRDC report uses a different product Synthol selectivity than that published in the literature by SASOL (see Table VI-5), this resulted in a higher gas make in the MRDC case.

oxidation to yield additional CO and H_2 which is then synthesized to yield an all-liquid output. As a result, the overall thermal efficiency of the SASOL II plant is less than 40 percent.(5)

The outputs of the Synthol reactor in the gasoline boiling range (C_5 - 180°F) have an intermediate* octane number of about 55 and require substantial upgrading to meet U.S. fuel standards.

In a study conducted for DOE in 1978, Mobil Research and Development Corporation (MRDC), with the assistance of Lurgi, prepared a detailed preliminary design of a U.S. plant employing SASOL technology. This design, which is fully described in Reference 1, has been used as the Base Case for the present study. The Base Case plant includes a sophisticated upgrading system, incorporating virtually every process used in a modern petroleum refinery, to maximize the yield of specification motor fuels from the Synthol products.

Table I-1 shows pertinent data for the Base Case plant when operated to produce liquid fuels and SNG as co-products, and when operated to produce an all-liquid output. In the mixed product mode, the daily plant output is 173.3 MM SCF for SNG and 19,591 B (barrels) of liquid fuels from 27.8 T/day of coal. Thermal efficiency (HHV) is 57 percent. Operation in the all-liquid mode more than doubles the liquid yield to 41,230 B/day, but efficiency is reduced to 44 percent.

---

*$\frac{\text{Research + Motor}}{2}$

TABLE I-1

SUMMARY DATA FOR SASOL-U.S. PLANTS

	MIXED OUTPUT	ALL LIQUID OUTPUT
Output:		
SNG (MM SCF/D)	173.3	------
Gasoline (B/D)	13,580	28,090
Other Liquid Fuels (B/D)	6,011	13,140
Total Liquid Fuels (B/D)	19,591	41,230
Total FOE (B/D)*	44,950	33,652
Input:		
Total Coal Used (M T/D)	27.8	27.8
Coal to Steam Plant (M Lbs/Hr)	416	416
Coal to Gasifier (M Lbs/Hr)	1,901	1,901
Steam to Gasifier (M Lbs/Hr)	1,700	1,700
Oxygen to Gasifier (M Lbs/Hr)	458	458
Efficiency (HHV)	57	44
Liquid Fuel Bbls. C_4^+/Ton Dry Coal	.92	1.94
Plant Construction Cost (MM $)	1,186.1	1,382.7
Capital Cost (MM $)	1,887	2,199
Gasoline Cost ($/Gal)**	1.33	1.51

*Fuel Oil Equivalent assuming 6 MMBtu/B.

**Prices for products other than gasoline are shown on inset. All prices are Oct. 1977$. Other financial parameters are summarized in the text.

PRICE OF FUELS OTHER THAN GASOLINE

PRODUCT	PRICE
SNG & C_3 LPG	$6.17/MMBtu
C_4 LPG*	Gasoline -$.30/MMBtu
Diesel*	Gasoline -$1.70/B
Fuel Oil*	Gasoline -$3.50/B
Alcohols	$.15/Lb

*Shown relative to gasoline price

Economic assessments are based on a 20-year plant life and 100 percent equity financing with a 12 percent Discounted Cash Flow (DCF). The required selling price (i.e., cost) for gasoline reported in Table I-1 has been computed under the assumption that the products other than gasoline are priced in accordance with the schedule indicated on the Table.*

The data show that the mixed output plant produces cheaper gasoline than the all-liquid ($1.33 vs $1.51). However, the cost of gasoline from the mixed output plant is profoundly affected by the price of SNG. MRDC derived a price of $6.17 per MMBtu (1977$) from a design study which showed that SNG could be produced for this cost from a single product SNG plant using dry ash Lurgi technology. The cost of gasoline from the mixed output plant would be greater than the all-liquid plant cost of $1.51 if the SNG price fell below $5.40/MMBtu. We thus believe that the all-liquid gasoline costs are more realistic.

The coal used in the postulated SASOL-U.S. plant is a 28 percent moisture Wyoming sub-bituminous having an assumed cost of $7/ton and a higher heating value of 8,509 Btu/lb. The cost cost is thus 41¢ per MMBtu. At this price, coal accounts for only 9 percent of the product cost. Coal costs could more than double without raising the product cost by more than 10 percent.

Capital charges account for 65 percent of the product cost. The remaining 26 percent of cost is dominated by maintenance costs

* All economic data in the body of this report are computed and reported in October 1977$.

and other factors which are proportioned to plant construction cost. Thus the gasoline price is approximately linearly related to plant construction cost; e.g., a 10 percent increase in construction cost would result in an increase in the gasoline selling price of almost 10 percent.

The estimates of construction cost given in Table I-1 are from MRDC (Reference 1). An independent verification of these estimates is beyond the scope of this study. In using the estimations, which are highly detailed in Reference 1, we have formed the judgment that the costs determined by MRDC are soundly derived and possibly conservative. We believe that MRDC cost data provides a sound basis for estimating the incremental costs associated with the modified plants considered in this study.. While we caution against the use of any absolute cost data, we feel the comparative ranking of the processes is valid.

1.3 Advanced Gasifiers

The dry bottom Lurgi gasifiers are the only large scale pressurized gasifiers which have extensive commercial experience. Their major disadvantages in an indirect liquefaction complex are the relatively high quantities of methane which they produce, and a high process steam requirement which results in a low overall thermal efficiency. Other disadvantages include inability to process coal fines or highly caking coals.

There are alternative gasifiers now in late stages of development which circumvent some of the limitations of the dry bottom Lurgi.

The impact on plant output and product cost resulting when these advanced gasifiers are substituted for the dry bottom Lurgi has been evaluated in this study. Gasifiers considered include a slagging modification of the dry ash Lurgi design developed by the British Gas Corporation (BGC) and Lurgi, and entrained flow gasifiers under development by Texaco and Shell-Koppers.

Outputs of the dry bottom Lurgi are compared with the outputs of the three advanced gasifiers in Table I-2. The higher efficiencies of the advanced systems are evident. It is also evident that the advanced systems produce a synthesis gas having an H_2/CO ratio of .48 to .68, as compared to 2.1 for the Dry Bottom Lurgi. Conventional Fischer-Tropsch synthesis reactors, such as the Synthol reactor, require an H_2/CO ratio of about 2.5. The output of the advanced gasifier must thus undergo a much greater water-gas shift (e.g., $H_2O + CO \rightleftharpoons H_2 + CO_2$) as a part of the gas preparation step. Our analysis reveals that this penalty is minor compared to the efficiency gains of the advanced gasification system.

Table I-3 shows pertinent data for indirect liquefaction plants employing the advanced gasification systems to produce an all-liquid product output. The plants are similar to the SASOL-U.S. Base Case except for minimal changes in process flows and equipment size required to accommodate the advanced gasification systems. Plants fully optimized to take advantage of the advanced gasification system would be expected to offer slightly higher technical and economic performance.

TABLE I-2

GASIFIER PERFORMANCE COMPARISONS

	DRY ASH LURGI	BGC LURGI	TEXACO	SHELL KOPPERS
Gas Composition (Mole %):				
H_2	23.0	21.9	27.6	30.9
CO	11.1	43.8	40.6	64.4
CH_4	6.7	5.2	.1	nil
C_2H_4, C_2H_6	.3	.3	nil	nil
CO_2	17.6	2.1	12.2	2.4
H_2O	41.0	26.3	18.9	1.4
Miscellaneous	.3	.3	.6	.9
H_2/CO Ratio	2.06	0.5	.68	.48
Energetics (MMBtu/Hr. LHV):				
Total Coal Used*	18,959	18,959	18,959	18,959
H_2 + CO Output	7,187	11,079	15,126	15,735
CH_4 + C_2 Output	4,854	3,067	52	nil
Naphtha Output	314	341	nil	nil
Tars/Oils/Phenols**	1,645**	1,791**	nil	nil
Total Output	12,355	14,487	15,178	15,735
Net Gasifier Efficiency+	70.1	77.7	77.0	83.0

*DAF Basis. Includes steam coal requirements for Dry Ash and BGC Lurgi. Does not include fuel for coal drying for Texaco and Shell Koppers

**Not included in totals--used for steam generation.

+As defined by Shinnar, Reference (13).

TABLE I-3

SUMMARY DATA FOR PLANTS EMPLOYING SYNTHOL SYNTHESIS & VARIOUS GASIFIERS (All Liquid Outputs)

	SASOL-U.S. BASE CASE	BGC LURGI GASIFIER	TEXACO GASIFIER	SHELL KOPPERS GASIFIER
Output:				
SNG (MM SCF/D)	------	------	------	------
Gasoline (B/D)	28,090	31,514	31,445	34,455
Other Liquid Fuels (B/D)	13,230	14,867	15,616	17,131
Total Liquid Fuels (B/D)	41,320	46,381	47,061	51,586
Total FOE (B/D)	33,652	37,776	38,308	41,996
Input:				
Total Coal Used (M T/D)*	27.8	27.8	27.8*	27.8*
Coal to Steam Plant (M Lbs/Hr)	416	247	------	------
Coal to Gasifier (M Lbs/Hr)	1,901	2,070	2,316	2,316
Steam to Gasifier (M Lbs/Hr)	1,700	453	------	46
Oxygen to Gasifier (M Lbs/Hr)	458	545	1,588	1,283
Efficiency (HHV)*	43	48	49	53
Liquid Fuel Bbls. C_4^+/Ton Dry Coal	1.94	2.18	2.21	2.42
Plant Construction Cost (MM $)	1,383	1,289	1,285	1,347
Capital Cost (MM $)	2,199	2,050	2,044	2,142
Gasoline Cost (1977$/Gal)**	1.51	1.24	1.23	1.16
Gasoline Cost (1980$/Gal)	2.00	1.65	1.64	1.55

*Does not include fuel used to dry coal; treated as an operating cost.

**Prices for products other than gasoline are given on Table I-1 inset.

The Table shows that the reduction in gasoline price resulting from the use of advanced gasifiers is quite substantial, amounting to about 18 percent in the case of Texaco and BGC gasification, and about 23 percent for Shell-Koppers.

All cost estimates produced in this report are in October 1977$ in order to maintain consistency with baseline data from Reference 1. August 1980 product prices shown in Tables I-3 and I-4 are approximations which were calculated by applying Neilson Refinery Cost Indices to the computed 1977$ results. Capital costs are escalated by 1.26. Operating costs, including coal, were escalated by 1.38. This results in an adjusted 1980 coal price of $9.68/ton, which is believed to be reasonable for the coal assumed.

1.4 Advanced Synthesis

The second generation advanced gasifiers discussed in this report all produce a synthesis gas with a H_2/CO molar ratio very much lower than that produced by the dry bottom Lurgi gasifier. The conventional Synthol Fischer-Tropsch reaction requires a synthesis gas having a H_2/CO ratio of 2.5 for synthesis of liquid hydrocarbons. The gas from BGC, Texaco and Shell-Koppers gasifiers will therefore require considerable water gas shift to make it compatible with Synthol operation requirements. The Kolbel reactor, that uses a three phase liquid slurry process, can synthesize liquid hydrocarbons from a gas having a low H_2/CO ratio. This means that little or no external water gas shift will be required for synthesis gases produced from advanced gasifiers if they are coupled to a Kolbel synthesis unit.

One purpose of this report is to analyze the combination of Kolbel synthesis with advanced gasifiers to determine if this coupling has significant economic and technical impact on the indirect liquefaction process. Although no commercial Kolbel synthesis units are in operation, there are sufficient data from the operation of a demonstration Kolbel plant at Rheinpreussen, Germany from 1938-53 to analyze the system in some detail. There are also data confirming the experience of the Rheinpreussen work from other investigators using bench scale equipment. Other small pilot plant experiments using Kolbel slurry reactors at the United States Bureau of Mines (1951) and at the Department of Scientific and Industrial Research in the U.K. (1953-61) failed to replicate the success of the Rheinpreussen plant but possible reasons for this are discussed in this report.

Table I-4 summarizes the results of the analyses for the combination of Kolbel synthesis reactor and advanced gasifier. The table only shows the impact for plants producing an all liquid output. Mixed output cases are described in the text. The most significant features of the analyses are the higher gasoline yields obtained using the Kolbel reactor, the higher overall thermal efficiencies of the plant and the lower capital cost and hence gasoline costs. The 16 percent increase in thermal efficiency from the Sasol-U.S. base case to the Shell-Koppers/Kolbel plant is highly significant and demonstrates the efficiency advantages obtained by both gasifier and synthesis substitution. A comparison

TABLE I-4

SUMMARY DATA FOR PLANTS USING KOLBEL SYNTHESIS
AND ADVANCED GASIFIERS
(All Liquid Outputs)

	SASOL-U.S. BASE CASE	BGC LURGI/ KOLBEL	TEXACO/KOLBEL	SHELL KOPPERS/ KOLBEL
Output:				
SNG (MM SCF/D)	------	------	------	------
Gasoline (B/D)	28,090	39,945	40,407	44,166
Other Liquid Fuels (B/D)	13,230	10,416	10,983	12,007
Total Liquid Fuels (B/D)	41,320	50,361	51,390	56,173
Total FOE (B/D)	33,652	41,506	42,332	46,272
Input:				
Total Coal Used (M T/D)	27.8	27.8	27.8*	27.8*
Coal to Steam Plant (M Lbs/Hr)	416	216	------	------
Coal to Gasifier (M Lbs/Hr)	1,901	2,100	2,316	2,316
Steam to Gasifier (M Lbs/Hr)	1,700	460	------	46
Oxygen to Gasifier (M Lbs/Hr)	458	553	1,588	1,283
Efficiency (HHV)	43	53	54	59
Liquid Fuel C_4^+/Ton Dry Coal*	1.94	2.31	2.35	2.57
Plant Construction Cost (MM $)	1,383	1,180	1,176	1,194
Capital Cost (MM $)	2,199	1,876	1,870	1,898
Gasoline Cost (1977$/Gal)	1.51	1.03	1.01	0.94
Gasoline Cost (1980$/Gal)	2.00	1.36	1.34	1.23

*Does not include coal used to dry coal.

of the Shell-Koppers/Synthol plant with an overall efficiency of 53 percent, shows that the further increase of 6 percent is attributable to the Kolbel synthesis unit. This thermal efficiency increase originates from the lower selectivity to light gases and the higher selectivity to gasoline boiling range hydrocarbons obtainable with Kolbel synthesis. Table I-5 illustrates the product distribution difference by comparing the outputs of the Synthol reactor as described in Reference 1 to the Kolbel reactor. Thus the SK/Kolbel combination produces very few C_1 and C_2 hydrocarbons that have to be reformed in an all liquids output plant. It is this reforming of large quantities of C_1 and C_2 hydrocarbons that accounts for the high thermal efficiency penalty associated with the production of all liquid outputs.

The 51 percent increase in the yield of gasoline for the SK/Kolbel case over the Base Case is also a considerable process advantage. The increase in product output combined with an overall decrease in capital cost for the SK/Kolbel case accounts for the low value of 94 cents/gallon ($1.23 1980$) for the price of gasoline. This represents a cost savings of about 40 percent over the SASOL-U.S. Base Case.

1.5 R&D Recommendations

Recent R&D in coal gasification has been directed toward the production of fuel gas and SNG. Gasifier R&D for the Synthane, Hygas, CO_2 Acceptor, Bi-Gas, and Exxon Catalytic processes has been directed toward maximizing the methane content of the product gas. Methane

TABLE I-5

PRODUCT SELECTIVITY FOR SYNTHOL AND KOLBEL
FISCHER-TROPSCH SYNTHESIS REACTORS

PRODUCT WT % OF TOTAL HYDROCARBONS	KOLBEL	SYNTHOL
$C_1 + C_2$	6.8	22.8
C_3	22.6	15.3
C_4	5.1	10.6
C_5 - 320°C	63.6	46.6
>320°C	1.9	4.6

production in gasification for liquid synthesis is a disadvantage since it must subsequently be reformed if only liquid products are to be produced.

The slagging BGC Lurgi is an excellent compromise gasifier and is well suited for use in a plant designed to yield SNG and liquid fuels as co-products. High temperature pressurized entrained flow systems, such as Texaco or Shell-Koppers, appear more advantageous if the production of liquid fuels is to be maximized.

Continued testing of the BGC Lurgi is recommended. Tests should investigate performance with western coals, and investigate the limits on gasification of tar, oils, phenols, and excess fines by bottom injection.

The major technical problems with entrained flow systems are associated with coal feed and the recovery of heat from the product output. Heat recovery is made difficult by the presence of particles and molten slag in the output gas.

The Texaco gasification plants currently under construction will provide important large scale experience with a pressurized entrained flow gasifier system employing a slurry feed.

Dry coal feed systems offer significant advantages over slurry feed systems, particularly if high moisture coals are used. R&D directed toward improved coal feed systems is ongoing under DOE sponsorship.

Other potential problem areas, including the development of improved heat recovery systems, are difficult to address at the PDU scale. There is a need therefore to acquire pilot scale experience with entrained pressurized gasification systems employing dry feed so that problems associated with safety and control, suitability of various coal types, life of refractory linings and other problems can be addressed.

The efficiency advantages offered by advanced gasifiers can substantially improve the technical and economic performance of indirect liquefaction plants, employing conventional Fischer-Tropsch reactors. Performance can be further improved by combining the advanced gasifiers with an alternative synthesis system such as the slurry phase Kolbel reactor. This additional improvement stems partly from a synergism which results from the ability of the Kolbel reactor to accept the low H_2/CO ratio synthesis gas produced by the advanced gasifiers. However, the most significant advantage of the Kolbel reactor stems from its greater selectivity toward the synthesis of gasoline.

This report has investigated the Kolbel liquid slurry phase reactor as one alternative to the fast fluid bed Synthol reactor used at SASOL. This combination has shown significant advantages in product cost, plant construction cost, liquid product selectivity and overall plant thermal efficiency. However, the successful continuous operation of a Kolbel unit for the production of gasoline boiling range liquid hydrocarbons has yet to be demonstrated in the United States. A research and development program should be initiated that would seek to establish the following:

- Confirmation of the Kolbel product distribution in its high selectivity to gasoline boiling range hydrocarbons and the low light gas make.

- Activity of the precipitated iron promoted catalyst system and studies of catalyst aging and ease of regeneration.

- Establishment of a regime where chemical rate control predominates unlimited by diffusional effects from the gas/liquid boundary to the catalyst surface in slurry phase reactors.

- The ability of the Kolbel slurry phase reactor to be scaled up to a commercial size unit by overcoming potential problems of uniform gas distribution in the suspension for large cross sectional area reactors.

- The ability of the Kolbel reactor to handle the low H_2/CO ratio synthesis gas feeds from the Shell-Koppers gasifier without shift.

The advantages of advanced technology gasification and synthesis systems shown in this study were quantified by substituting the advanced systems for conventional SASOL systems with minimal changes in overall process design. This approach was made necessary by the limited level of effort available for this study. The contribution of more advanced technology to indirect liquefaction would be further enhanced by optimization of the total system. We recommend that analytical efforts in this area be pursued.

2.0 INTRODUCTION

Importing of crude oil into the United States is forecast to continue for the foreseeable future. The impact of the predicted volume of imported oil on balance of payments and national security necessitates a continuing effort to examine all viable liquid fuel alternatives.

Conversion of coal to liquid fuels via Fischer-Tropsch is an important option. A commercial Fischer-Tropsch plant, using SASOL technology developed in South Africa, could be built in the U.S. today with minimal risk. SASOL technology has evolved over 50 years culminating in the construction of SASOL II with an output corresponding to 40,000 Bbl/D. This will be followed by SASOL III with an equivalent throughput.

In addition to its immediate availability, Fischer-Tropsch technology produces liquids which appear to be more benign biologically than the crude liquids from direct liquefaction. Finally, the production of diesel fuel and jet fuel from the Fischer-Tropsch liquids is projected to be lower in cost than those fuels derived from direct liquefaction of coal. While gasoline will remain the major transportation fuel, the demand for diesel and jet fuel is forecast to grow at a much greater rate than the demand for gasoline. In effect, direct and indirect liquefaction complement each other in filling the need for a spectrum of transportation fuels.

The basic SASOL technology is about 25 years old. Even though significant improvements have been made in the process during SASOL I operations and incorporated in SASOL II and III, many of the shortcomings of the process persist in the newest plants. These limitations impact unfavorably on the flexibility of the process, capital and operating costs, process efficiency, product selectivity and liquid yield.

In the meantime, progress has been made in the development of improved coal gasifiers, advanced synthesis processes and improved product upgrading methods. These unit operations represent the three key steps in Fischer-Tropsch technology. While these improved versions are in the research or pilot plant stage, the effect of incorporating these into hybrid Fischer-Tropsch processes can be evaluated by analysis. This type of analysis can assist DOE in its R&D planning.

Specifically, this study will use a recent MRDC-Lurgi assessment of Fischer-Tropsch,[1] involving a SASOL type plant at a U.S. location. We will disaggregate the SASOL process into individual process steps and determine unit capital and operating costs, efficiencies, product flows and product costs. Three advanced gasifiers -- BGC-Slagging Lurgi, Texaco and Shell-Koppers will be substituted for the Dry Bottom Lurgi. The effect of this substitution on costs, efficiencies and output will be determined.

A critical assessment will be carried out of advanced process concepts for conversion of low H/CO ratio synthesis gas to liquid fuels by Fischer-Tropsch.

Low H/CO synthesis gas is a characteristic product of higher efficiency gasifiers of interest. Conventional Fischer-Tropsch will not accept such low ratio feed without prior H/CO ratio adjustment, using a water gas shift. This external shift can result in a loss of process efficiency and increased capital cost.

Coupling of these advanced synthesis techniques with the higher efficiency gasifiers in a hybrid Fischer-Tropsch version will be evaluated. The status and limitations of each process combination will be highlighted.

An R&D program will be proposed, emphasizing the most promising leads from this study. The data base requirements for testing and developing these advanced processes, and their optimization, will be developed.