ALTERNATE COAL PRODUCTS

Session Chair: **Dr. Michael L. Jones**
Energy & Environmental Research Center, UND
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   by: Dr. David Gray
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"A COMPARATIVE TECHNO-ECONOMIC ANALYSIS OF COPROCESSING, DIRECT COAL LIQUEFACTION AND RESID UPGRADING"

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A COMPARATIVE TECHNO-ECONOMIC ANALYSIS OF COPROCESSING, DIRECT COAL LIQUEFACTION AND RESID UPGRADING

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ABSTRACT

This report documents a study of the developmental status and future potential of coal/oil coprocessing technology. It provides a techno-economic analysis of coprocessing as it compares to other alternative technologies of resid upgrading and coal liquefaction, and presents a comparative technical and economic analysis of coal liquefaction using the HRI catalytic two-stage liquefaction (CTSL) process, the HRI two-stage coprocessing technology, and resid upgrading using the H-Oil process. The conclusion is that coprocessing could be a transitional technology between resid upgrading and coal liquefaction, and would be economically more favorable than coal liquefaction until crude oil prices climb to around 40 $/bbl.

BACKGROUND

The U.S. Department of Energy (DOE) has been supporting several development efforts to demonstrate the technical and economic feasibility of coprocessing. As part of this effort, they requested that MITRE undertake a comparative economic analysis to identify economic conditions favorable to coprocessing.

This paper reports on the results of this techno-economic analysis performed to assess the relative economic potential of the coprocessing of coal and petroleum resid compared to the other alternative technologies of resid upgrading alone and coal liquefaction. All three of these technologies can use ebullated-bed reactors to accomplish the conversion of coal, coal-derived resid, and petroleum resid.

Two of the successful, commercially proven resid hydrocracking technologies use ebullating-bed reactors. These are the H-Oil[1] and LC-Fining[2] processes. Both of these essentially similar technologies use high-pressure ebullating-bed reactors and hydrotreating catalysts. Feed oil and hydrogen gas enter the reactors at the bottom, and the upflow velocity expands the catalyst bed into a state of ebullation. The bed expansion is controlled by an internal recycle oil pump. H-Oil process installations are located at the Texaco refinery in Convent, Louisiana, and in Kuwait and Mexico. Husky Oil Operations is currently designing an H-Oil unit in Canada to upgrade Lloydminster and Cold Lake heavy oils. LC-Fining units are located at the Amoco refinery in Texas City, and at Syncrude Canada's bitumen upgrading plant in Alberta.

These ebullating-bed reactors are also the key components in several technologies for the direct liquefaction of coal. Lummus-Crest used LC-Finer reactors as the second-stage, together with a short-contact-time thermal first-stage in their Integrated Two-Stage Liquefaction (ITSL) process.[3] At the Wilsonville coal liquefaction test facility, H-Oil reactors are used for both first- and second-stages in the Close-Coupled ITSL process.[4] Hydrocarbon Research Incorporated (HRI) uses two close-coupled H-Oil reactors in their Catalytic Two-Stage Liquefaction (CTSL) process.[5] Two of the current development efforts in coprocessing also utilize the ebullated-bed reactor. The Lummus-Crest

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coprocessing concept[6] uses LC-Finers, and the coprocessing technology being developed by HRI[7] uses H-Oil reactors and the same configuration as used for direct coal liquefaction.

There are several incentives for the development of coprocessing technologies. Since coprocessing upgrades both resid and coal simultaneously, it represents an intermediate technology to produce high-value distillate from poor-quality and low-cost feedstocks. The major plant components needed for coprocessing are commercial because of the availability of ebullated-bed reactors. There is also some evidence that coal may facilitate heavy petroleum resid upgrading. It has been suggested that heavy metals from the resid may preferentially deposit onto the coal ash rather than onto the catalyst.[8]

DATA SOURCES USED IN ANALYSIS

For coprocessing, this analysis uses data provided by HRI from their process demonstration run Phase 2, Bench Run No. 1.[7] These data were obtained during continuous bench-unit operations using Ohio 5/6 coal and Cold Lake resid as feedstocks. Subsequent to this bench-scale run at a nominal throughput rate of about 50 pounds of coal per day, HRI has conducted tests using these bench-scale conditions at the 3-ton-per-day level using their process development unit (PDU). Since the PDU data were not available, the bench-scale test results were used as the basis for scale-up in the MITRE analysis.

Experimental data on the HRI CTSL coal liquefaction process were also obtained from continuous bench-unit operations. The run selected for this analysis was Run 227-32 that used Illinois #6 Burning Star coal as feedstock.[5]

For the resid-only upgrading case, experimental data were obtained from a forty-one day demonstration run on Cold Lake resid that was performed by HRI in their 30-barrel per day H-Oil process development unit.[1] During this run high conversions of resid to distillate were achieved by using vacuum bottoms recycle. This demonstration run was conducted by HRI for the Alberta Oil Sands Technology Research Authority (AOSTRA).

METHODOLOGY

This comparative analysis was accomplished by developing computerized models that simulate conceptual commercial-scale plants.[9] Performances of the technologies were estimated from the experimental results cited above. The conceptual plants were all scaled to produce 100,000 barrels per day of liquid products. The models calculate feedstock requirements, plant fuel, hydrogen and energy needs, and final product yields and selectivities. The raw products are of differing quality and are hydrotreated in the model to produce distillates of common quality so that fair comparison is possible.

The computer model includes all of the unit processing steps necessary to convert the feedstocks to final products. In the coal liquefaction case, this includes coal handling and preparation, coal liquefaction, product recovery, hydrogen purification, solids/liquids separation, hydrogen production via coal gasification, and all the associated off-sites. For the coprocessing case, the model is very similar and includes coal and resid preparation, coprocessing, product recovery, hydrogen purification and vacuum distillation, hydrogen production via coal gasification, and associated off-sites. In the resid-only case, the model includes the H-Oil reactor section, product recovery, hydrogen purification, hydrogen production via coal gasification or steam reforming of natural gas, and associated off-sites.

In addition to performing energy and material balances, the models estimate the total installed cost of the conceptual plants, the total capital requirements, the operating costs, and the required selling prices of raw and hydrotreated products. Product prices are calculated from a discounted cash-flow analysis for a specified set of financial parameters.

Three cases are considered in this analysis. For case 1, the direct coal liquefaction case, figure 1 shows a schematic of the overall materials flow for the CTSL technology. The flows are based on 100 pounds of moisture-free Illinois #6 coal as fresh feed. Solids/liquids separation is accomplished using the ROSE-SR critical solvent deashing (CSD) process. Case 2, coprocessing, is shown schematically in figure 2. Flows are based on 50 pounds of moisture-free Ohio 5/6 coal and 50 pounds of Cold Lake resid to give a total input of 100 pounds of fresh feed. Solids/liquids separation is accomplished using vacuum distillation. Case 3, resid only upgrading, is shown in figure 3. Flows are based on 100 pounds of Cold Lake heavy oil. No deashing process is needed, but vacuum distillation is required to separate unconverted bottoms for recycle.

RESULTS OF ANALYSIS

Table 1 shows a summary of the feedstocks and products for conceptual commercial plants based on the data sources described above. The commercial plants are sized to produce 100,000

TABLE 1

CONCEPTUAL COMMERCIAL PLANT FEED AND PRODUCT SUMMARY (PLANTS SCALED TO PRODUCE 100,000 BPSD OF RAW PRODUCT)

	Coal Liquefaction HRI CTSL		Coprocessing HRI		Resid Upgrading Only H-OIL	
Feedstocks						
Coal to Liquefaction TPD(AR)	27,322		11,536		0	
Coal to Steam Plant	2,669		1,461		733	
Coal to Hydrogen Production	9,540		4,369		1,853	
Total Coal to Plant	39,531		17,365		2,646	
Oil to Upgrading TPD	0		10,406		17,208	
BPD	0		57,973		95,200	
Products	TPD	BPD	TPD	BPD	TPD	BPD
Naphtha	5,076	36,118	3,454	25,247	3,149	24,395
Middle Distillate	8,575	53,495	8,135	52,442	6,505	43,187
Heavy Distillate	1,856	10,387	3,724	22,311	5,231	32,418
Total Raw Product	15,507	100,000	15,313	100,000	14,885	100,000
Hydrotreated Product	15,430	106,850	15,107	104,614	14,672	101,611
Gasoline	14,786	114,330	14,477	111,937	14,060	108,724

barrels per stream day (BPSD) of raw distillate. In the CTSL plant, coal is required for liquefaction, steam generation, and gasification to produce process hydrogen. This is also the situation for the coprocessing plant, but here 58,000 BPD of Cold Lake resid is also processed in the coprocessing reactors. In the resid-only plant, coal is used for plant steam and for gasification to produce hydrogen. Coal gasification in this case is comparable to the other two cases that use coal for hydrogen production.

In order to compare the different quality products from the different processes, the MITRE model simulates the hydrotreatment of the raw products to a common hydrotreated product. The costs of performing this hydrotreatment and of converting the hydrotreated product to gasoline are also computed in the model. From these costs an equivalent crude value is obtained. Equivalent Crude is defined as the price a refiner can afford to pay for crude oil that would allow him to produce gasoline for the same price as synthetic gasoline. Thus the differential between the equivalent crude and the raw product price is a measure of the added value of the synthetic crude to the refiner.

Table 2 shows a summary of the economic data for conceptual commercial plants based on the three technologies. Construction costs are broken down by plant area, and the total capital costs are

TABLE 2

CONCEPTUAL COMMERCIAL PLANT ECONOMIC SUMMARY

	Coal Liquefaction HRI CTSL	Coprocessing HRI	Resid Upgrading Only H-OIL
CAPITAL AND OPERATING COSTS			
Plant Construction Cost ($1000)			
Liquefaction	1,286,594	924,358	662,932
Solids Removal	172,224	0	0
Hydrogen Production	757,083	485,608	280,493
Balance of Plant	534,949	364,581	247,623
Total Construction Cost	2,750,850	1,774,546	1,191,048
Total Capital	4,358,360	2,941,057	2,098,213
Operating Costs ($1000/yr)			
Coal (22.70 $/ton)	296,130	130,084	19,820
Oil (16 $/Bbl resid)	0	306,097	502,703
Other Operating	371,923	265,873	203,546
By-product Credit	110,472	89,460	36,178
Hydrotreating	127,326	95,020	44,421
Total Net Operating Costs	684,907	707,614	734,311
PRODUCT COSTS $/Bbl			
Raw Product	38.95	33.45	31.52
Hydrotreated Product	40.07	34.72	32.35
Gasoline	42.69	37.81	35.75
Equivalent Crude	32.90	28.24	26.27

given. Operating costs include the cost of coal feedstock at $1/MMBtu (22.70$/ton) and of resid at 16$/barrel. Table 3 shows the economic assumptions used in calculating the annual revenue requirement from which the required selling prices of the products are calculated. These required selling prices are shown at the bottom of table 2 for raw product, hydrotreated product, and gasoline. The equivalent crude value is also shown, which is calculated from the gasoline price, assuming a $6/barrel refiner's margin.

TABLE 3

ECONOMIC ASSUMPTIONS USED FOR ALL ANALYSES

Equity	25 percent
Project Life	25 years
Tax Life	16 years
Income Tax Rate	34 percent
Price Escalation*	0
O and M Escalations	0
Fuel Escalation	0
General Inflation	3 percent
Return on Equity	15 percent
Interest on Debt	8 percent
Construction Period	5 years

*Escalation defined as inflation over and above general inflation.

In order to investigate the favorable economic conditions for coprocessing, a series of sensitivity analyses were performed to determine the impact of feedstock costs on the required selling prices for these three technologies. Figure 4 shows the results of such an analysis for various costs of resid, assuming that the value of product gas is equal to resid on a thermal basis. Raw product selling prices are shown, and coal cost is assumed to increase at half the rate of resid on a thermal basis. This shows that coprocessing would be the preferred, lowest-cost technology for a range of resid costs from 21 to 28$/bbl. Above 28$/bbl, CTSL becomes economically preferred and below 21$/bbl, resid upgrading would be cheaper.

There is obviously a relationship between resid cost and crude oil price. This relationship does change with oil price, but historically the ratio of resid to crude cost is usually in the range from 0.66 to 0.9.

Figure 5 shows a plot of equivalent crude against crude oil price, assuming that resid value is 2/3 that of crude. The parity line for resid equal to 2/3 crude oil price is also shown for reference. The economically attractive regime is that area to the right of the parity line. With resid at 2/3 oil price, coprocessing is economically favorable for oil prices greater than 30$/bbl. Coprocessing appears to be economically favored compared to direct coal liquefaction and resid upgrading for crude oil prices between 33 and 42 $/bbl.

In conclusion, this analysis has shown that the economic window of opportunity for coprocessing occurs at resid, raw product, gasoline and crude oil prices of potential commercial interest. Coprocessing could be a transitional technology between resid upgrading and coal liquefaction, and would be economically more favorable than coal liquefaction until crude prices climb to around 40 $/bbl.

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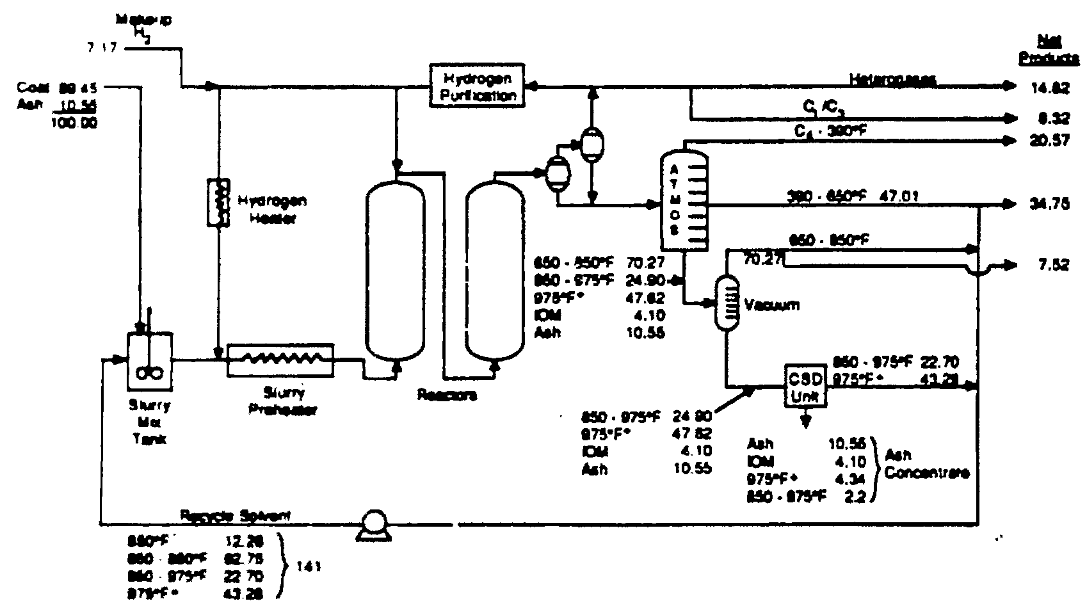

FIGURE 1 - HRI CTSL OPERATIONS—ILLINOIS NO. 6 BURNING STAR BENCH RUN 227 - 32/24

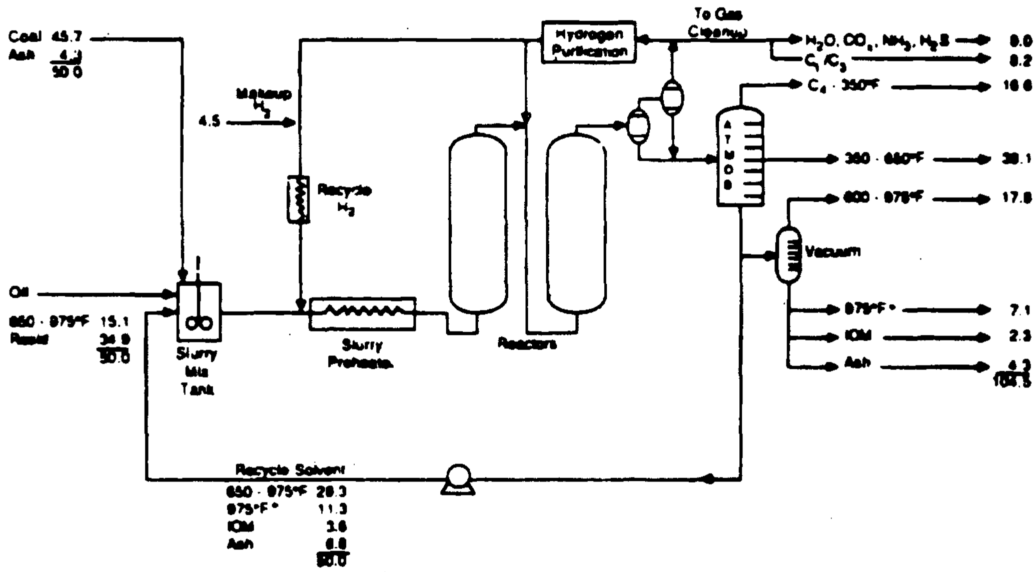

FIGURE 2 - HRI COPROCESSING CASE–PHASE 2 BENCH RUN 1/25

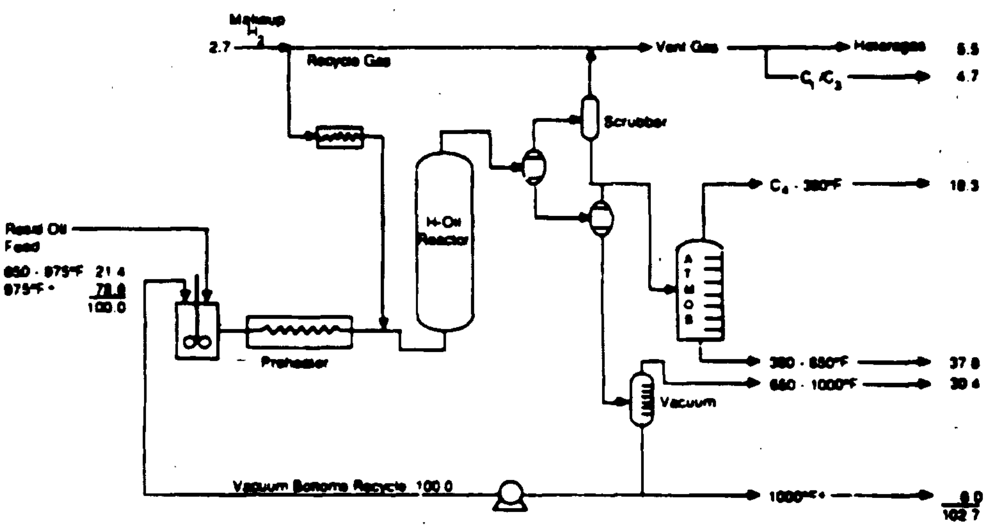

FIGURE 3 - RESID UPGRADING ONLY CASE H-OIL

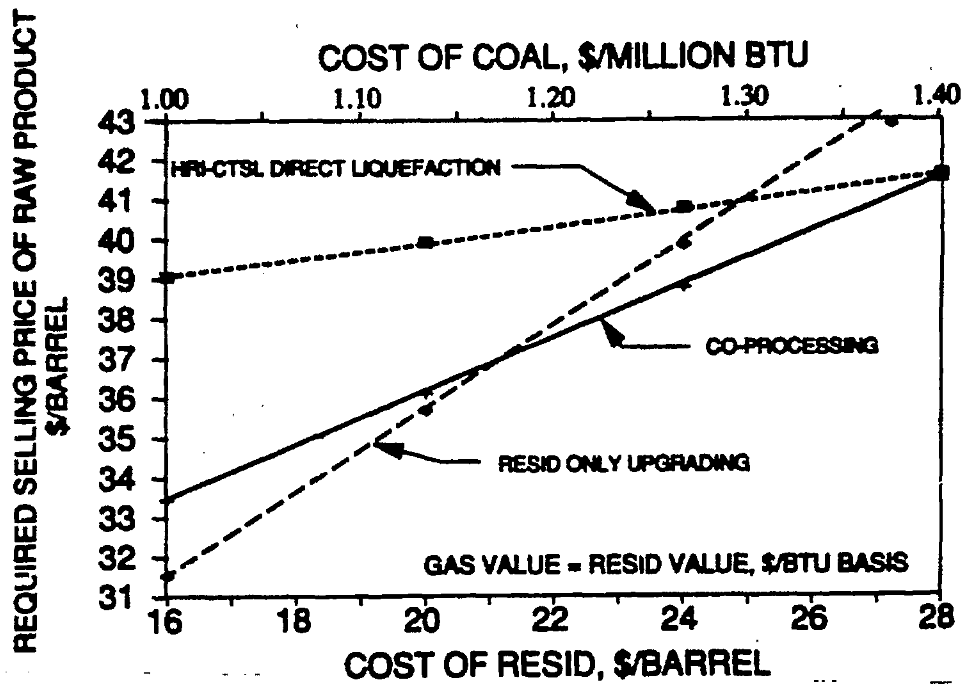

FIGURE 4 - REQUIRED SELLING PRICE OF RAW PRODUCTS VS RESID COST AND COAL COST

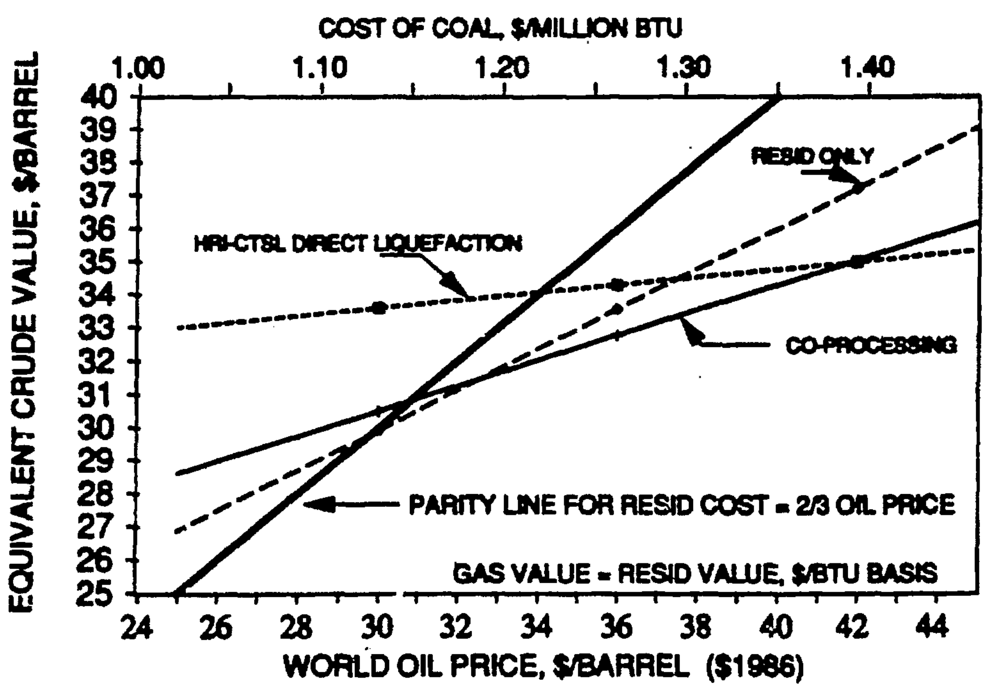

FIGURE 5 - EQUIVALENT CRUDE VALUE VS CRUDE OIL PRICE (RESID = 2/3 CRUDE)

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"UPDATE ON THE SYNFUELS INDUSTRY IN THE REPUBLIC OF SOUTH AFRICA"

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UPDATE ON THE SYNFUELS INDUSTRY IN THE
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ABSTRACT

This paper deals with the developments in the Synfuels technology at Sasol since the commissioning of the Sasol Two and Sasol Three plants in 1982. The specific areas covered are coal gasification, synthesis plants and the development of modern high technology reactors to reduce capital and maintenance costs of future Synfuel plants.

Emphasis is further placed on the coproduction of chemicals in Synfuel plants to increase profitability. An important aspect namely that the fuels from the Sasol Synthol process can meet the new specifications for reformulated gasoline are also dealt with in the paper.

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Introduction

When synfuel technology or the production of synfuels is discussed, South Africa is invariably mentioned together with Sasol. Sasol ventured into synthetic fuels during the 50's and expanded its production capacity many times over following the energy crisis during the 70's, thereby producing a significant percentage of South Africa's total liquid fuel consumption. Until recently Sasol remained the only company in South Africa involved in the production of synthetic automotive fuels.

In 1988 the South African government approved a new project, this time for the production of synthetic fuels from offshore natural gas. Although Sasol synthesis technology is involved, Sasol decided not to participate in the project. It was Gencor, a South African mining house, which obtained a 30% option in the project. The other shareholders are the Central Energy Fund (with a 50% participation) and the Industrial Development Corportion or IDC (with a 20% participation). Gencor also accepted responsibility for project management and the subsequent operation of the Synfuels complex known as Mossgas. The name is based on the town "Mossel Bay", where the onshore synthesis plant is being built. Gencor Limited was established in 1980 after the merger of two leading South African mining houses, General Mining and Finance Corporation and Union Corporation, both founded at the end of the last century.

The history of the synfuels industry in South Africa has clearly shown that in isolation the production of synfuels from coal cannot compete with crude oil. This leaves, as I said earlier, two alternatives. To drop production of synfuels altogether and rely, exclusively on imported crude oil or to maintain a limited synfuels activity supported by oil refining and chemicals production. In South Africa the second alternative was chosen and I believe correctly so. Although crude oil is freely and cheaply available now, this commodity will not be available forever. It is therefore important that an atmosphere be maintained conducive to the development of alternative fuels processes. In South Africa we improved on the conventional Fischer Tropsch route, but extensive work has also been done on the direct liquifaction of coal. Elsewhere in the world development work is concentrating on hydrogen and/or electricity as an automotive fuel and no doubt there are other routes to replace the present conventional liquid fuels.

The successful commissioning of the two Sasol plants in Secunda during 1980 and 1982 is by now well known. In this paper the history of these mammoth projects and the lessons learnt, will be left aside and the focus will be on developments at Sasol since the Sasol Two and Sasol Three plants were designed and commissioned. The changing strategy towards a greater emphasis on products other than gasoline and diesel fuel will also be dealt with.

The progress of development and commercialisation of processes at Sasol should be seen against the background of the choice of processes for the original Sasol One plant in the early 1950's. Pioneering work was, amongst others, done regarding the Lurgi, Phenosolvan and Rectisol processes. The two Fischer-Tropsch reactor types, namely the circulating fluidized bed (Synthol process) and the fixed bed (Arge process) were developed to commercialisation for the first time. With perseverance and hard work the processes in Sasol One were improved up to the point where reliability and performance reached levels acceptable in the petrochemical industry.

In the process selection for Sasol Two and Sasol Three only commercially proven processes were selected. This was a major factor in the smooth commissioning of the plants and it contributed to the fact that the plants were completed and commissioned on schedule and within budget.

Over the years process optimization and improvement in equipment design continued. The competitiveness of the Sasol Operations has been maintained and improved due to continued increases in plant throughputs and productivity improvements. Many of these are incremental in nature and do not attract particular attention. However, in an environment where local inflation has been running at about 15% p.a. for several years, and the revenue from synfuels is coupled to the international crude oil price, special efforts were required to maintain profits.

Sasol employs 33 000 workers and it has 28 000 private shareholders. In 1989 US Dollar value, the replacement cost of the Sasol Two and Sasol Three plants was some 12 000 million US Dollars. The annual turnover of the Sasol group came to 1,3 million US Dollars during the previous financial year. The attributable after tax profit was 180 million US Dollars.

Gasification

The original 9 Lurgi gasifiers at Sasol One have a diameter of 3,7m and were designed for 26 000 m^3n/h raw gas. They were scaled up to 3,8m and improved during the 1970's and altogether eighty of these units were installed at Sasol Two and Sasol Three. In 1981 a 4,7m diameter prototype Lurgi gasifier was commissioned at Sasol One and this unit has been available for large scale application since 1982. This gasifier produces between 90 000 and 100 000 m^3n/h raw gas, which is about 70% more than the installed capacity of the Secunda gasifiers. The development regarding gasifiers also covered aspects such as coal and ash locks, coal, gas and ash distribution, steam and oxygen feed and the automation of gasifier control.

Synthol Fischer-Tropsch synthesis

Parallel to developments in catalyst formulation and the combined optimisation of process conditions and catalyst characteristics, a separate reactor development project was tackled in 1981. The traditional Synthol reactors are using the circulating fluidized bed (CFB) concept. By its nature the circulation of catalyst requires significant amounts of energy and special precautions had to be taken to take care of the erosive properties of the iron based catalyst. The concept of a "fixed fluidized bed" (FFB), i.e. a traditional fluidized bed without external catalyst circulation was very attractive. Starting from pilot plant work and progressing through semi-commercial scale, a full commercial scale reactor using the fixed fluidized bed concept has been commissioned in March 1989 at Sasol One. It was built as a parallel unit to one of the three Sasol One Synthol reactors and it has a nominal capacity equal to that particular reactor. The commissioning of the reactor went very smoothly, and it is meeting, and in some aspects surpassing, design expectations.

Besides the obvious advantage of a much simpler and thus cheaper construction and a lower linear gas velocity, the fixed fluidized bed (FFB) reactor has much lower operating costs and maintenance is expected to be significantly cheaper than the circulating fluidized bed reactors. It is expected that the capital cost of a synthesis plant based on the FFB reactors in stead of the CFB reactors could be as much as 60% lower.

The commercial scale fixed fluidized bed reactor still uses cyclones to separate the product gas and entrained catalyst as is the case with the circulating fluidized bed reactors. Semicommercial scale tests are under way to prove the suitability of sintered metallic filters instead of cyclones. The successful commercialisation of this technology drastically reduces the complexity of down stream processing and would lead to much better thermal efficiencies since the present quench system could be eliminated.

On-line catalyst addition and withdrawal provides the basis for considerably extended on stream times.

The fixed fluidized bed reactor provides significant cost advantages for any new large scale Fischer-Tropsch plants and thus further improves the competitiveness of Sasol technology for the production of fuels or chemicals from gas or coal.

Fixed bed Fischer-Tropsch sythesis

At Sasol One five fixed bed Fischer-Tropsch reactors were built in the 1950's. In 1987 a sixth reactor was commissioned successfully. The older reactors operate at about 25 bar, whereas the sixth reactor can operate up to 45 bar. It has similar dimensions to the older units, but throughput is higher in proportion to the pressure. Results obtained have been highly satisfactory. Product properties also meet the stringent wax specifications and catalyst life (time on stream) is similar to that of lower pressure runs. The conversion and selectivities were as predicted by the computer model developed in house.

Slurry Bed Fischer-Tropsch

Similar advantages to that described above for the fixed fluidized bed reactor are in principle possible for slurry bed operation. This includes very good temperature control as well as good heat and mass transfer. Pilot scale work confirmed the possibility of getting high conversions and desirable selectivities in slurry beds. The semicommercial reactor used to commercialise the fixed fluidized bed reactor will now be converted to a slurry bed reactor. One of the crucial steps to be tested is the catalyst separation from the final wax products. Laboratory scale testing provided results that indicate that a suitable economical technique can be developed.

If the slurry reactor development is successful, it will mean that Sasol will have four reactor systems available for Fischer-Tropsch applications. It is anticipated that the fixed fluidized bed will be the most generally applicable system for the production of a combination of gasoline, diesel fuel and chemicals. The slurry bed reactor will probably be more suitable for diesel fuel and wax products.

Chemicals

Currently Sasol markets in excess of 100 different products. These can be categorised as follows:

Fuels	(gasoline, diesel fuel, industrial gas, fuel oils etc.)
Solvents	(aromatics, alcohols, acetone, methyl ethyl ketone etc.)
Waxes	(ranging from soft to very hard and including special products such as oxidized and crystallized waxes)

Nitrogenous products	(ammonia, a full spectrum of fertilizers as well as porous ammonium nitrate for mining explosives).
Coal co-products	(creosotes, phenol, cresylic acids, pitch etc.)
Polymers	(a Polypropylene plant came on stream in February 1990)
Explosives	(a wide range of mining explosives)
Chemicals	(ethylene, propylene, paraffins, sulphur etc.)

The main benefit of the Sasol Synthol process in olefin production is the fact that olefins have only to be recovered from the Synthol products which is a much cheaper process than the olefins from a naphtha cracker.

Further recent expansions to Sasol's activities include the erection of a fertilizer plant, an explosives plant, solvent purification and blending facilities and phenol purification facilities. These are examples how the profitability of Sasol is being increased by expanding on the basis of existing competitive advantages.

Ethylene production at Secunda amounts to 315 000 t.p.a.

A 120 000 tons per annum polypropylene plant was commissioned during February 1990 at Secunda. Associated with this plant is a 150 000 tons per annum propylene recovery plant. The polypropylene is aimed at replacing imported polypropylene and additionally a substantial quantity will be exported.

Further opportunities are developed based on co-products from the Sasol processes, and also from downstream derivatives of some of these products. Areas for which such opportunities are evaluated, include speciality solvents, cresylic acid derivatives, annode and electrode coke, speciality olefins and derivatives, aldehyde derivatives, wood preservatives and speciality waxes.

In 1987 the capacity of the tar acid refining plant was doubled and since further process improvements were made, a minimum phenol purity of 99,8% can be achieved consistantly. This coal based phenol is now successfully competing with synthetic phenol in international markets.

Technology

The South African Mossgas enterprise, employing Sasol Synthol technology to convert off-shore natural gas into liquid fuels, entered into a licensing agreement with Sasol. This covered the Synthol process (circulating fluidized bed) and associated processes. Technical assistance with the design of the on-shore facilities and commissioning assistance were also provided by Sasol. The plant is now under construction. This was an excellent opportunity to extend the application of Sasol technology to a natural gas feed, which opens the way for similar plants elsewhere in the world where gas is available.

For further process developments Sasol has the benefit of having its Reasearch and Development facilities within the Sasol One plant perimeter. The scaling up of processes to prototypes can be accommodated within Sasol One, where adequate infrastructure is available. The quantities of product streams are such that the risk of large scale testing is clearly much less than at Secunda, but the scale is adequate to prove commercial viability and to determine operating costs reliably.

Environmental Aspects

Representatives from the coal industry are fully aware of the environmental aspects of coal use. Coal as an energy source is increasingly being labelled as a dirty and environmentally unacceptable. Problems ranging from acid rain to the greenhouse effect are being ascribed to coal. These problems are all related to coal in its use as a feed for power generation and I do not want to take sides in this argument.

However, the problems of coal in a boiler are largely eliminated when considering a coal to synfuels plant. The sulphur is not converted to Sulphur dioxide (SO_2) which is difficult and expensive to remove from flue gas, but is gasified to Hydrogen Sulphide (H_2S) which can be recovered as sulphur.

Nitrogen oxides which can add to the acid rain/photochemical smog problem are not formed in a gasifier, but rather nitrogen in the coal is recovered as ammonia, a valuable and useful raw material. In addition the ash in the coal is recovered in a coarse form which has very little chance of ever polluting the air.

Optimal use and re-use of water is a clear requirement in South Africa, where droughts occur sporadically and rivers have limited capacities both regarding the supply of water and their potential to dilute effluents. Significant progress was made at Sasol Two and Sasol Three to recycle various grades of water to the extent that a Zero Effluent plant is achieved.

A cooling tower system using the stripped gas liquor from the gasification plant was developed to commercial operation at Sasol. This technology was subsequently transferred to the Great Plains plant in North Dakota. Recently the co-use of stripped gas liquor and Fischer-Tropsch reaction water in a cooling water system was also successfully piloted.

The development of an anaerobic digestion plant for the treatment of industrial effluent was a significant step forward to have a robust effluent treatment system which has both a wide range tolerance for the spectrum of organic components of the feed streams and it can withstand concentration shocks in the feed very well. This process was successfully piloted to degrade the Fischer-Tropsch acids in the reaction water. It has not been scaled up to full commercial size at Secunda, since consideration is now given to two other options, namely bioprotein production and acid extraction. The process will however be used at Mossgas.

Coal gasification and Fischer-Tropsch Synthesis plants can be built and operated today, as shown by the Sasol Two and Sasol Three plants, in an environmentally acceptable way.

In addition it is not generally known, but the primary fuels produced by Sasol at Secunda are amongst the most environmentally acceptable in the world. The gasoline that is produced has zero sulphur content, is low in aromatics and the level of oxygenates means a relatively high octane number. It has also been proved that an oxygenate containing fuel, as a result of the lower combustion temperature results in a generally lower level of reactive exhaust constituents.

The blending of synthetic gasoline with alcohols (ethanol as well as higher fuel alcohols) presented a particular challenge to Sasol. The physical properties of such blends can, by using known refining technology and blending techniques, be tailored to meet typical international standards. The addition of a whole range of additives in most automotive fuels constitute a cost element which deserves particular attention. Sasol erected very sophisticated Research and Development facilities to optimise and characterise fuel additives. Whereas carburettor corrosion with alcohol containing gasoline occurs with certain alloys used for carburettors, Sasol has now developed its own package of additives to the point where a formal guarantee is issued to clients who used Sasol fuel.

The diesel fuel is a zero sulphur fuel with a high cetane number and a paraffin content that will result in a lower particulate emission level than any normal refinery fuel.

The fuels from Secunda could with a minimum of refinery modification be able to meet the specifications for the new reformulated gasoline and diesel fuels presently being proposed in the USA as the specifications for the new reformulated gasoline and diesel fuels presently being proposed in the USA as the specifications for the year 2000 and beyond.

Conclusion

The theme of this conference is "Opportunities in the Synfuels Industry". The experience at Sasol has shown that synfuels industry is and should be an ongoing one. Even after 35 years in production, there is an ever increasing number of projects being taken through laboratory and pilot scale operation to commercial implementation. The key to success lies in selecting the winning products from a range of possibilities, to be able to build on specific sustainable competitive advantages and to market the products at prices and with a quality that ensure competitiveness.

The improvements in Sasol and its associated technologies have contributed to significant improvements in the synfuel process economics by reducing operating and capital costs and by increasing plant throughputs and reducing maintenance time. This has kept Sasol technology up to date and confirmed a position to compete economically not only in the traditional gasoline and diesel fuel sectors, but also increasingly in the chemicals field. This technology is equally well suited to coal or lignite gasification as to natural gas based plants.

I believe I have also shown that coal, when used to produce a combination of synfuels and chemicals as is done today at Sasols One, Two and Three is, in essence the feedstock to a Coal Refinery. The Coal Refinery offers opportunities for the production of by-product and co-product chemicals and for the establishment of a chemical industry based on the unique raw materials. In addition the fuels produced in such a Coal Refinery can easily be formulated to meet or exceed the most stringent specifications for environmentally friendly fuels which can be expected in the future.

/mc919

"GLOBAL PERSPECTIVES: TRENDS AND ISSUES"

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Grand Forks, North Dakota

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ENERGY POLICY ANALYSIS
July 20, 1990

"conditions leading to crisis events in energy supply during the 1970s are again developing as we enter the 1990s..."

- *Sustained Growth*
- *Low Inflation*
- *Accelerating Energy Demand*
- *Passive Energy Policy*
- *Active Environmental Policy*

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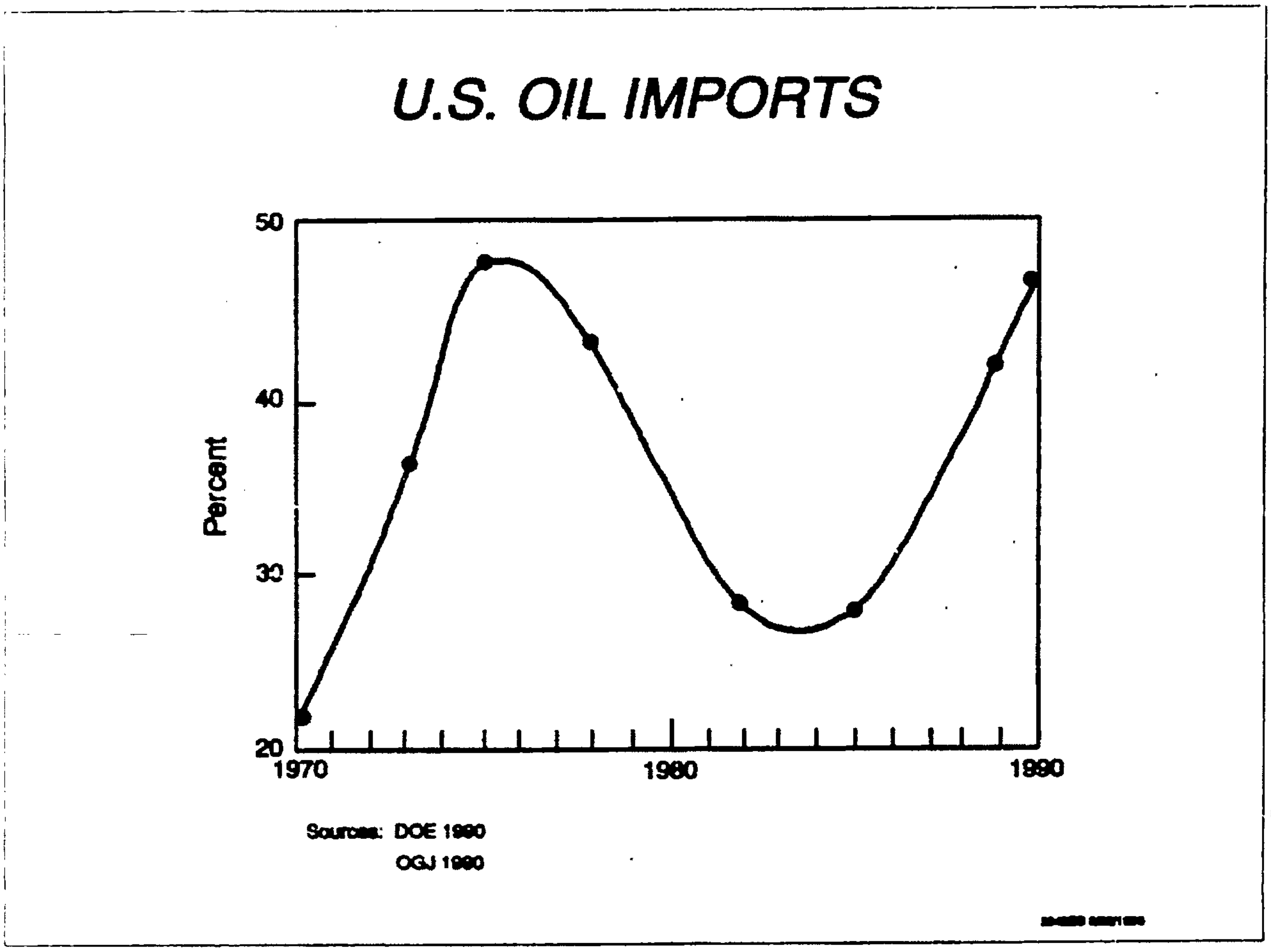
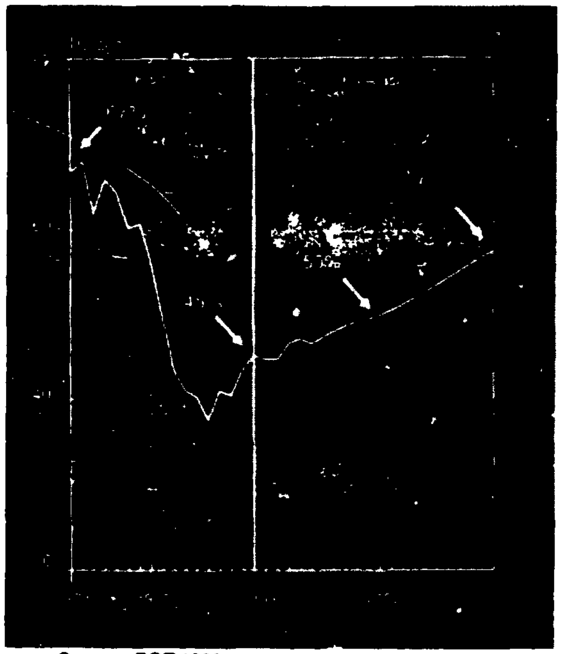
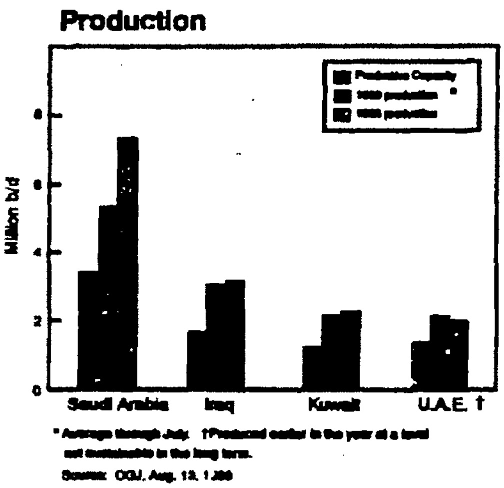

U.S. OIL IMPORTS
50
40
30
20
Percent
1970
1980
1990
Sources: DOE 1990
OGJ 1990

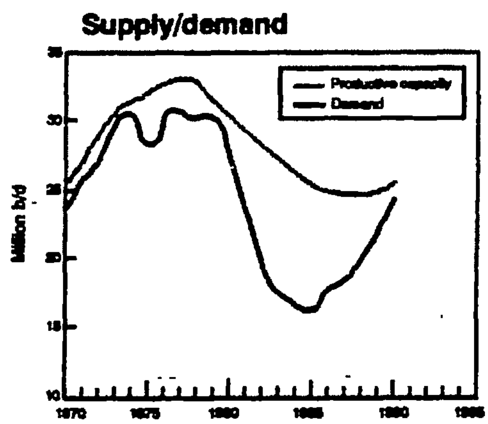
OPEC IN WORLD OIL MARKETS



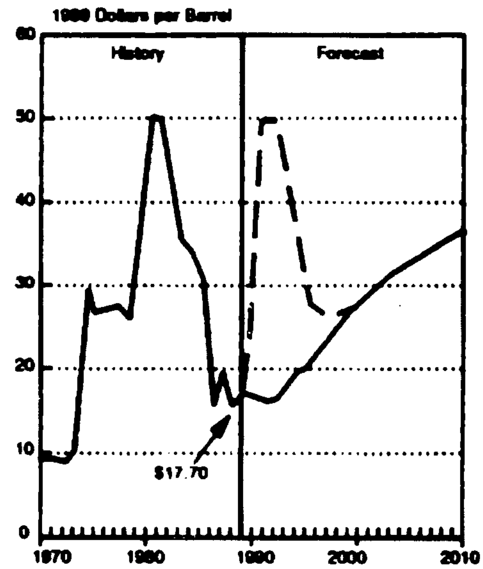
Source: DOE 1990

SUPPLY AND DEMAND FOR OPEC OIL





OIL PRICE RISE SCENARIOS



Source: DOE 1990

ENERGY MARKETS ARE CYCLICALLY UNSTABLE

- *Accelerating energy demand is periodically constrained by resource availability and producing capacity.*
- *Resources enter the market at widely differing costs, forcing marginal oil producing capacity from U.S. stripper wells costing $25/Bbl to compete with Saudi Arabian crude costing $1/Bbl.*
- *The concentration of low-cost oil supply in OPEC results in monopolistic pricing whenever world demand approaches production capacity. Response to energy supply shortfalls have built-in time lags which cause major interruptions in supply to affect prices for about 5 years.*

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ENERGY MARKETS... (cont.)

- *A small energy shortfall has a disproportionately large effect on price in the short term, which also allows a small increment of reserve capacity to stabilize the market.*

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NATIONAL ENERGY POLICY

The underlying role of government energy policy is to enable and restrain energy markets to protect public interests.

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FOSSIL ENERGY RESERVES

Resource	10^9 Bbl Oil Equivalent	World Reserves, Principal Reserves,%	U.S. Reserves, %
Oil	990	OPEC 60%	4%
Gas	650	USSR 40% OPEC 30%	5%
Coal	3300	US 29% USSR 26% Europe 18% China 11% Australia 7% S. Africa 6%	29%

Source DOE 1989

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CONSENSUS GOALS

- *Strict Protection of Health, Safety and the Environment*
- *Secure Energy Supply*
- *Stewardship of Scarce Domestic Resources*
- *Efficiency and Conservation in Energy Use*

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HISTORY OF U.S. ENERGY SUPPLY POLICY

The U.S. response to instabilities in energy supply over the past two decades has varied between two extremes, neither of which alone has proven effective.

1970s - "Project Independence"

1980s - Return to Reliance on Market Forces

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ELEMENTS OF A SUSTAINABLE U.S. ENERGY SUPPLY STRATEGY

- *Energy markets are global--U.S. energy independence is not a viable option.*

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ELEMENTS OF A SUSTAINABLE U.S. ENERGY SUPPLY STRATEGY (cont.)

- *Management of inherent instability in price and supply of oil is possible based on reduced dependence on oil and incentives for reserve producing capacity, including measures for:*

  - *conservation*
  - *improved efficiency*
  - *long-term fuel switching*
  - *regional supply agreements*
  - *a dynamic strategic oil reserve*
  - *a two-tier domestic market providing incentives for reserve*

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ELEMENTS OF A SUSTAINABLE U.S. ENERGY SUPPLY STRATEGY (cont.)

- *Increased reliance on domestic coal and natural gas can be fostered by means that are economically and environmentally sound*

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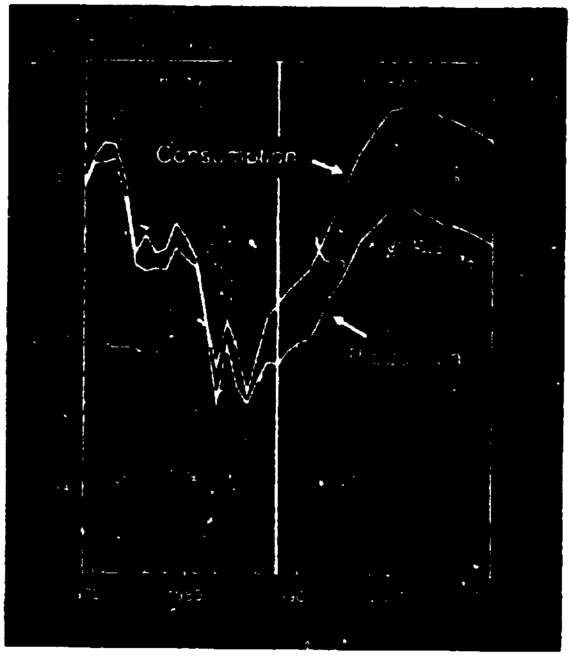
GROWTH IN U.S. GAS MARKETS

U.S. RESERVES-1000TCF



Source: DOE 1990

ELEMENTS OF A SUSTAINABLE U.S. ENERGY SUPPLY STRATEGY (cont.)

- Measures for Gas:
  - gas price deregulation by 1993 as scheduled
  - open access to gas markets
  - broadened gas markets, e.g. natural gas fueled vehicles
  - increased use of gas by electric utilities under long-term contracts
  - improved efficiency in gas use based on turbine, combined fuel cell technologies, e.g. turbines, combined-cycle systems, fuel cells
  - liquid fuels from natural gas, e.g. methane

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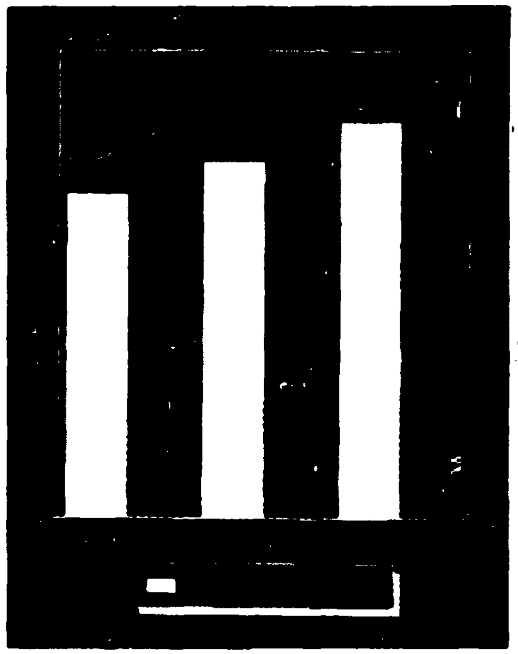
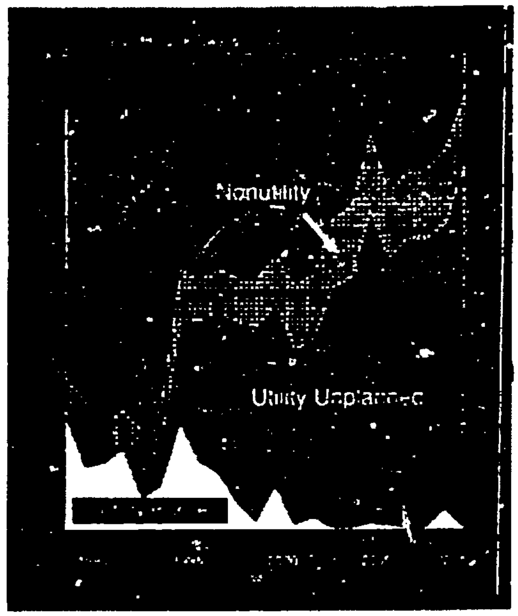
COAL'S SHARE OF TOTAL U.S. ENERGY PRODUCTION



Source: DOE 1990

MAJOR ADDITIONS IN U.S. ELECTRICAL CAPACITY REQUIRED BEYOND THE MID-1990'S



Source: DOE 1990

ELEMENTS OF A SUSTAINABLE U.S. ENERGY SUPPLY STRATEGY

- *Measures for coal:*
  - *renewed support for large synfuel projects,*
    - *e.g. coal-water fuels at $12/Bbl oil equivalent*
    - *underground coal gasification at $30-$40/Bbl*
    - *synfuel liquids include methanol at $30-$60/Bbl*
  - *a sustained clean coal program for all coal ranks and regions*

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ELEMENTS OF A SUSTAINABLE U.S. ENERGY SUPPLY STRATEGY (cont.)

- *Measures for coal (cont.):*
  - *regulatory reform affecting coal use in areas of:*
    - *the Abandoned Mine Reclaimation Act*
    - *eminent domain for coal slurry pipelines*
    - *review of the Staggers Rail Shipment Act*
    - *independent power producers*
  - *support for coal exports from the Western U.S. and Alaska*
    - *quality standards*
    - *preparation methods*
    - *transportation infrastructures*

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ELEMENTS OF A SUSTAINABLE U.S. ENERGY SUPPLY STRATEGY (cont.)

- *Measures for coal (cont.):*
  - *expanded coal R&D focused on:*
    - *coal preparation*
    - *efficient combustion and heat engine technologies*
    - *fuel cells*
    - *integrated emissions controls*
    - *strategic fuels for military environmental applications*
    - *coal refinery concepts for co-producing char, oil and gas*

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NEEDED ENVIRONMENTAL INITIATIVES

- A high level federal mandate to assess the impact of global warming at the earliest possible time

- Clean Air Ammendments providing

  - SO_2 and NO_x emissions control based on the full potential of the best available technology
  - a market driven approach to compliance
  - freedom of choice on fuel and technology
  - repeal of the 1977 percentage SO_2 reduction requirements
  - plant averaging
  - flexibility for retrofit, repowering and clean-coal demonstration projects
  - extension of compliance to 2005 for high-efficiency technologies

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