FIGURE 12

Conclusions

Integration of the many elements of a large commercial venture:

- Requires unusual agreement and cooperation among industries.
- Places unprecedented demands on participant's resources.
- Increases vulnerability to change and delay.
- Magnifies impact of government policy and actions.
- Can be done.

THE ROLE OF COAL GASIFICATION IN THE FUTURE SUPPLY AND DEMAND FOR GAS ENERGY IN THE U. S.

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The Role of Coal Gasification

Coal gas should be, in commercial production, a minor source of gas by 1985. It should begin to make a major gas supply contribution between 1990 - 2000.

Introduction

Natural gas continues to be the largest source of energy produced in the United States, accounting in 1979 for one-third of U.S. primary energy production, and about 25% of total U.S. fuel consumption.

Enactment of the Natural Gas Policy Act of 1978 (NGPA) has materially enhanced the prospects for U.S. production of conventional and supplemental sources of gas energy because of its phased removal of federal field price controls and its special exploration incentives in high cost areas of known gas potential. Taken together, natural and supplemental gas can potentially supply the U.S. with as much as 30 quads (10^{15} Btu) of energy by the year 2000, as shown in Table I below:

Table I

Potential Gas Supplies Through 2000

(10^{15} Btu)

	1980	1990	2000
Conventional gas	18-19	15-17	12-14
Potential Supplementals			
Canada & Mexico	1.6	2.1	1.8
SNG (naphtha based)	.5	.5	.5

LNG imports	.4	2.0	3.0
Alaskan pipeline gas	-	1.6	3.6
New Technologies	-	1.8	5.0
Coal gasification (High-Btu)	-	.6	3.3
TOTAL	20.5-21.5	23.6-25.6	29.2-31.2

As Table I illustrates, natural gas (methane), naturally occuring or synthetically produced, can maintain its current market share of total domestic energy consumption through the year 2000 and beyond. Coal based synthetic natural gas will not be a major supply source of gas until at least 1990, but should begin to make a minor supply contribution by 1985. Overall, coal gasification technology can contribute 3.3 Tcf of gas, or about 10% of total gas supplies, by 2000. A comparable quantity of gas can be supplied to domestic markets from Alaska; with new technologies, principally unconventional drilling processes, having the potential to contribute nearly 50% more gas than coal gas (although technology development will be necessary). To date, the gas industry has put more emphasis on coal gasification, relative to most other supplemental sources of gas, because our industry has a high degree of confidence in both the technological and economic parameters of coal gasification.

Overall, the market justification for coal gasification has changed dramatically since the mid-1970's. Today the gas industry beleives coal gas will be competitive with other sources of gas by the time most coal gasification facilities are completed. Coal gasification can no longer be justified on the basis that "we are running out of gas". NGPA phased deregulation, as well as aggressive national action on all supplemental sources of gas promises a strong gas supply picture through 2000.

U.S. Coal Use and Plans for Gasification

Despite hopes following the 1973-1974 oil embargo of vast increases in the use of coal -- which is the largest proven fossil energy resource in the United States -- American coal use has increased by only 10% during the past six years. In fact, U.S. coal use has remained nearly constant over the past three years, increasing by only 4% during the period 1976-1979. It is generally agreed that the following three factors have significantly dampened coal demand in the U.S. during the 1970's, thereby inhibiting coal production: (a) the high cost of new coal-burning equipment and facilities compared with gas or oil-fired equipment, (b) strict enforcement of the Clean Air Act with its stringent 1977 amendments, and (c) -- frankly -- the continued availability of oil on the world market.

As we enter the 1980's, the third of these factors that have inhibited U.S. coal conversion -- ample world oil supplies -- is clearly disappearing. World energy -- both its supply and demand -- is firmly entrenched as the most crucial international economic problem affecting all nations; this includes both developed and developing nations, and consuming as well as producing nations. Nonetheless, the first two factors mentioned above remain substantial barriers to vastly increased U.S. use of its coal resources. Coal gasification holds the promise of addressing effectively both of these remaining two U.S. coal use constraints: high capital costs of coal-fired end-use equipment and major environmental problems.

Synthetic gas from coal can begin to make a modest contribution to U.S. gas supplies during the 1980's, potentially rising to the equivalent of 300,000 barrels per day of oil or more by 1990. The first several U.S. commercial synthetic coal gas plants are proposed for Western U.S. locations and will utilize the Lurgi process followed by a methanation step. Following successful demonstrations at full commercial scale during the 1980's synthetic coal gasification at a potpourri of U.S. locations, and using a variety of coal and technologies, can combine to produce far greater quantities of synthetic pipeline gas, potentially contributing 3.6 Tcf (about 1.6 million barrels/day oil equivalent) to U.S. gas supplies by the year 2000.

Economics

The gas produced from high-Btu coal gasification plants built over the next five years will be a competitive fuel for residential, commercial and industrial consumers. Product cost estimates made by project sponsors indicate coal gas will be competitive with foreign oil and unconventional natural gas. Plants projected to come on line in the mod-1980's have forecast product prices conpetitive with pipeline supplies in the first year of operation.

As you are aware, cost projections for high-Btu coal gas escalulated steadily since the early 1970's. Most projects now estimate a project cost at the tailgate of the plant of between $5.00 - $5.50/mbtu (1980 constant dollars). This price is roughly equal to what the U.S. pays OPEC today for lighter grades of crude oil. The OPEC price increase precipitated by the Iranian revolution has resulted in coal gas finally "catching-up" with the cost of imported oil.

Regulatory Impediments to Coal Gasification

Given successful resolution of the Great Plains Coal Gasification Project tariff in court, the principal regulatory constraint to commercialization of coal gasification technology will shift from the economic, technical and regulatory barriers faced by individual projects to general marketing constraints on gas.

Regulatory and legislative impediments to gas demand have the potential of effectively blocking the timely completion of those gas supply projects outlined in Table I (including coal gas). These supplemental gas supplies will only be developed if there is a strong demand pull for gas from the industrial sector and the gas industry remains financially healthy. The financial health of the gas industry in turn is tied to the maintenance of a strong industrial gas market, which provides a stable, non-temperature sensitive demand for gas service.

There are two major regulatory impediments to gas use by industry: (1) Title II of the Natural Gas Policy Act (NGPA), incremental pricing; and (2) the Powerplant and Industrial Fuel Use Act (FUA). While Phase 2 of incremental pricing has been vetoed by Congress, Phase 1 remains in effect, significantly impacting the interstate industrial boiler market. The repeal of all of Title II is therefore a high priority of the gas industry.

The FUA places numerous restrictions upon the use of natural gas by industry and powerplants. Of particular concern, from the standpoint of displacement of oil with natural or synthetic gas, are the provisions of Section 301 (a) of the FUA. These provisions ban any use of natural gas by existing powerplants after 1989 -- while simultaneously imposing interim (i.e., pre-1990) restrictions which effectively prevents gas from displacing oil in non-coal capable electric powerplants. The establishment by DOE/ERA of temporary public interest exemptions, which allow existing powerplants to shift from oil to gas, is only a short-term solution -- since Section 311(h) of the FUA limits the total duration of such exemptions (including extensions) to 5 years. Consequently, the repeal of Section 301 (a) is necessary.

A potential regulatory problem to the gas industry concerns the Department of Energy rate design study mandated by the Public Utility Regulatory Policies Act of 1978 (PURPA). That study, published May 9, 1980 appears to advocate an economic cost (i.e., modified marginal cost) approach to gas rate-making. A principal rationale cited in the Department of Energy study was the necessity of such a rate-making scheme to prevent chaos in the post-1985 deregulated natural gas market.

It is our position that the most effective means of keeping down wellhead gas prices and "preventing chaos" in the deregulated gas market is to encourage supplemental gas projects. This can only be done by maintaining a financially strong gas utility industry. As previously pointed out, industrial customers provide gas companies with a stable, non-temperature sensitive market. This market, in turn, will give the gas industry the financial resources to construct supplemental gas projects.

Supplemental gas projects impact gas prices in two ways: (1) they provide a source of gas which is often not tied to the price of oil; and (2) they displace oil imports taking pressure off the world oil market. Since deregulated gas prices will probably seek crude oil parity, lower oil prices will mean lower deregulated gas prices.

The new danger to coal gasification projects is based on increased regulation of the gas market by the Federal government. These attempts by the Federal government to take an active role in the pricing of gas to end-users has the potential of undermining the financial stability of the gas industry and artificially depriving coal gas of a market.

Summary

Coal gasification has finally come of age economically in terms of competitive prices. It is presently an economic source of energy for most stationary applications, and should become increasingly cost competitive over time. The gas industry perceives coal gas as one of several diverse supplemental sources of gas it will rely on between 1985 - 2000.

THE REAL COST OF SYNTHETIC FUELS

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Introduction

The major purpose of this paper is to bring forth the real cost of an almost forgotten synfuel--intermediate-Btu gas. Our experience is that a large fraction of the energy community limits its thinking almost exclusively to SNG when they are called on to deliberate about coal gasification. Results of EPRI studies of the costs of intermediate-Btu gas will be presented. The results should be useful to those who need more complete knowledge of coal gasification products.

Costs of intermediate-Btu gas will be presented in mid-1979 dollars. This may not be acceptable to those who believe future inflation needs to be included in cost analyses. Accordingly, another purpose of this paper is to present an engineering economics methodology which permits the estimator to forget about using inflation. Its use has never really been required, and it is hoped that this paper will convince the synfuel community that this is true.

The Forgotten Synfuel - Intermediate Btu Gas

In the early 1970's, the common wisdom was that intermediate-Btu gas could not be produced at as low a cost as could low-Btu gas. This was based on the feeling that since air was free and oxygen plants were expensive and consumed much energy, low-Btu gas had to be a winner.

In EPRI's early days, it became apparent that intermediate-Btu gas had many more applications in electric power systems than did low-Btu gas. EPRI had this question studied by Fluor Engineers and Constructors, Inc., and the results indicated that the costs and thermal efficiencies were virtually the same for the two products, for most gasifier types.*

This finding led, in part, to EPRI's support of the development of the Texaco and British Gas Corporation's (BGC) oxygen-blown gasifiers.

The Texaco gasifier is working well in Germany at a 150 ton per day scale. A 1000 ton/day demonstration plant employing the Texaco technology will soon be tested in a 100 MWe gasification-combined cycle plant to be constructed at Southern California Edison's Cool Water generating station in Southern California.

EPRI's analysis of the BGC slagger led us to believe that the cost of intermediate-Btu gas from this gasifier could be considerably lower

*"Economics of Current and Advanced Gasification Processes for Fuel Gas Production," EPRI AF-244, July 1976.

than that produced by using a Lurgi dry ash system (based on Illinois No. 6 coal).

Yet the slagger is being considered a competitor to the Cogas system for high-Btu gas production. Though some of the virtues of the slagger should lead to lower cost high-Btu gas, we believe that its first priority development should be as an intermediate-Btu gas producer.

Our reason for believing this is the potential for producing intermediate-Btu gas (IBG) at required selling prices that can be considerably lower than prices of other synfuels and liquid petroleum fuels.

Required selling prices for EDS liquids and IBG will be presented later. They were based on the data in Table 1.

Table 1

	Costs when Processing Illinois No. 6 Coal		
	Exxon EDS	Lurgi Dry Ash	Slagging Gasifier
Plant Capacity:			
Barrels Per Day	59,800	28,390*	35,180*
Billion Btu Per Day	335	159	197
Erected Plant Cost:			
Million Mid-1979$	$1,900	$711	$383
Per Daily Barrel	$31,770	$25,040	$10,890
Plant Operating and Maintenance Cost:			
Million Mid-1979$/Year	$113.2	$36.7	$19.7
Cost of Illinois No. 6 Coal Feed:			
Mid-1979 $/MMBtu	$1.06†	$1.06†	$1.06†
Coal Feed Capacity:			
Short Tons Per Day	24,000	10,000	10,000
Annual Capacity Factor:	0.85	0.9	0.9

*Product heating value expressed as barrels of EDS liquid heating value equivalent.

†Plus 1%/year real cost increase.

The numbers in the above table were taken from an Exxon design study for the EDS plant[1] and from EPRI studies for the gasification plants[2]. When

[1] "EDS Coal Liquefaction Process Development," Phase IIIA, Volume II, Exxon Research and Engineering Co. for Department of Energy, Feb., 1980, Report No. FE-2353-20.

[2] EPRI AF-782 and AF-244.

costs in those studies were expressed in pre-1979$, they were inflated to mid-1979 at an inflation rate of 8%/year. Though Exxon used a capacity factor of 0.8 in their study, we have arbitrarily chosen to increase this to 0.85.

The financial parameters used in the required price estimates were:

	EDS Plant	IBG Plants
Fraction of Total Capital Financed by: Common Equity	1.00	0.50
Debt		0.50
Fraction of Plant Investment Financed by Debt*	0.50	
Required Return on Equity	8.5%/yr.	7.1%/yr.
Interest on Debt	4.0%/yr.	3.0%/yr.
Inflation Rate	Zero	Zero

*This is an alternate case to measure the effect of loan guarantees.

The reader may wonder why returns on equity and interest rates are so low, relatively speaking. The reason is discussed in more detail in a section following. At this time, it is only necessary to state that these rates are proper to use when no future monetary inflation is perceived, which is the case in this estimate.

Based on the above costs and financial parameters, the following required prices were calculated:

	Price Required Mid-1979$
EDS Liquid Product*	$36.50/Bbl
EDS Liquid Product†	$31.00/Bbl
Intermediate-Btu Gas:	
Lurgi Dry Ash$^{\delta}$	$24.00/5.6 MMBtu**
BGC Slagger$^{\delta}$	$13.00/5.6 MMBtu**
BGC Slagger With 40% Contingency	$18.20/5.6 MMBtu**

*Total capital financed with 100% common equity funds.

†Plant financed with a 50% loan guarantee.

$^{\delta}$Plants owned and operated by regulated investor owned utility.

**5.6 MMBtu is the higher heating value of a barrel of EDS product.

A few comments are appropriate regarding the above prices:

- The prices for the liquid products are prices required for a minimum acceptable rate of return. They assume no "real" increase in the price of competing fuels, such as foreign crude oil. If foreign crude oil is assumed to increase in "real" price, then the required prices, as defined, can decrease. Calculation of such reduced prices is shown in a later section.

- On the other hand, the required prices for the gas products cannot decrease in the event of a real increase in the price of competing fuels, for they are regulated to the producing utilities actual costs and return requirements.

- The price shown for the Lurgi dry ash system is believed to be conservative for two reasons: (1) Illinois No. 6 coal is not an optimum feedstock for this gasifier, and (2) process improvements have been made since the cost estimate was performed. It is believed that analysis of a modern Lurgi system using a Western coal as a feedstock would result in a required price substantially less than the $24/5.6 MMBtu shown.

- Since the estimate for the gas produced by the BGC slagger was prepared, experimental work on this system indicates that the plant will not perform as originally estimated. For this reason, a 40 percent contingency is applied to the price estimated for the original plant configuration.

But, even with the 40% contingency, it is seen that gas from the slagger can be more than competitive with clean products from foreign crude oil. Further, even the conservative estimate for the dry-ash Lurgi system results in a competitive price for intermediate-Btu gas.

The Inflation Dilemma

To this point, required prices have been presented without taking inflation into account.

If ten experts in synfuel economics were asked their estimates for the required selling price for a particular synfuel, experience teaches that at least five and perhaps ten different answers would be given. This variance occurs even when capital, operating, and coal or shale costs are essentially the same. This difficulty can be attributed to the belief that since inflation exists, analyses need to include inflation. Accordingly, since it is highly likely that the ten experts will use different rates of inflation, they will produce widely varying estimates. Users of the estimates will then be at a loss to normalize the various estimates and to appreciate their real meaning.

Those who performed studies in engineering economics in the halcyon days of the 1950's and early 1960's may remember how easy it was to publish a number and have it understood by virtually everyone. Now the situation is considerably different. If you do not use inflation in your analysis in an inflationary period, your numbers are not accepted on the grounds that you have not accepted a prevailing fact--that future inflation is likely. On the other hand, if you use inflation, you must publish numbers such as $80 per barrel for a liquid fuel, $12 per million Btu for a gaseous fuel, $50 per ton for coal, etc. Such numbers lose their meaning when they are compared to present costs of competing fuels. Also, you are faced with comparing your numbers with those produced by others. Attempts at these comparisons are usually futile because the odds are that different people will choose different future inflation rates.

A Solution to the Inflation Dilemma

It will be shown that it is not necessary to include inflation in engineering economic analyses that are to be used for comparing prices of different products. This will be done by producing an "inflation independent price." This is a price in present dollars which if allowed to increase with any rate of inflation will yield the same discounted cash flow rate of return in real dollars. When we say any rate of inflation, we include a zero rate of inflation. This is a necessity to establish our position that inflation need not be included in analyses.

The Methodology Applied to Exxon Donor Solvent Liquids from Coal

Before proceeding with the methodology, it is acknowledged that Exxon Research and Engineering used essentially the same methodology in their engineering design studies of the EDS process. This presentation extends proof of the methodology by showing that the inflation independent price is equivalent to other types of price calculations such as year-by-year revenue requirements including inflation, and levelized year-by-year revenue requirements, also including inflation.

Two important points should always be kept in mind when estimating future revenues (prices) required for synfuels or for any other product. These are:

- If a company is willing to accept a fractional return of x per year in a non-inflationary period, then it should be willing to accept a return of (1 + x)(1 + infl) - 1 in an inflationary period, where infl is the fractional rate of inflation. For example, if a return of 0.085/yr. (8.5%/yr) is acceptable without inflation, then at say an 8%/yr. inflation rate, a rate of return of (1.085)(1.08) - 1 = 0.1718/yr. (or 17.18%/yr.) would be equivalent. The proof of this follows. If a dollar was invested at 8.5%/yr. for n years and inflation was at 8%/year, the value in constant dollars of the receipts after n years would be:

$$\$1 \frac{(1.085)^n}{(1.08)^n} = \$1(1.0046)^n, \text{ and}$$

  the real rate of return is less than 0.5%/yr. It is readily seen that to re-establish the real rate of return to 8.5%/yr., the preceeding expression needs to be multiplied by 1.08^n, which is equivalent to saying that the rate of return needs to be 17.18% per year.

- Similarly, if banks are willing to loan money in the absence of perceived future inflation at an interest rate of x/year, the interest rate would be:

$$(1 + x)(1 + \text{infl}) - 1$$

  at a given perceived inflation rate.

The above are important points, for we see many constant dollar analyses in which interest rates and returns on equity are overstated. In a non-inflationary period, loans to corporations are made at interest rates as low as 2 to 4%/year, and acceptable returns on equity are as low as 6 to 8% per year.

The most common mistake in the synfuel literature is the use of incorrect returns on equity and loan interest rates when constant dollar analyses are presented.

For example, an engineering company recently used a 15%/year return on common equity in a constant dollar analysis, and showed that intermediate-Btu gas from a Lurgi system would need to be priced at $8 per million Btu. If a more proper 8.5%/year return had been used, the $8 would drop to about $6. Further, if the plant had been assumed to be owned by a regulated utility instead of being financed by 100% non-regulated common equity, the required price would drop to approximately $5 per million Btu.

Another example, a constant dollar analysis of required synfuel prices was presented using 12% per year as required return on equity. The only test of sensitivity to return on equity was done at 15% per year!

For the purpose of the material presented below, we have used the following financial parameters:

	No Inflation	8%/Year Inflation*
Return on Common Equity:		
Non-Regulated Company	8.5%/yr	17.18%/yr
Interest on Debt:		
Non-Regulated Company	4%/yr	12.25%/yr

*At other inflation rates, rates of return were calculated using the equation: (1.085)(1 + infl) - 1 = fractional rate of return/yr.

The Distortion Caused by Inflation

Two price-versus-time curves are presented in Figure 1. The curve labeled "EDS Liquids" represents the price required to yield a return of 17.18 per cent each year on the unrecovered investment at the beginning of that year. This type of price is usually referred to as a "year-by-year price" and is commonly using in regulated utility industries, for these industries are regulated to a more or less fixed rate of return on depreciated capital each year. As can be seen, the $/Bbl prices really do not mean too much in terms of being able to relate them to today's prices of alternative fuels.

A partial answer to this dilemma is to plot the price of a competitive fuel (crude oil) with its current price (assumed at $35/barrel) inflating at the same inflation rate (8%/year) as used in the EDS liquids price estimates. This plot, also shown in Figure 1, helps to a small degree. It shows that year-by-year EDS liquid prices would

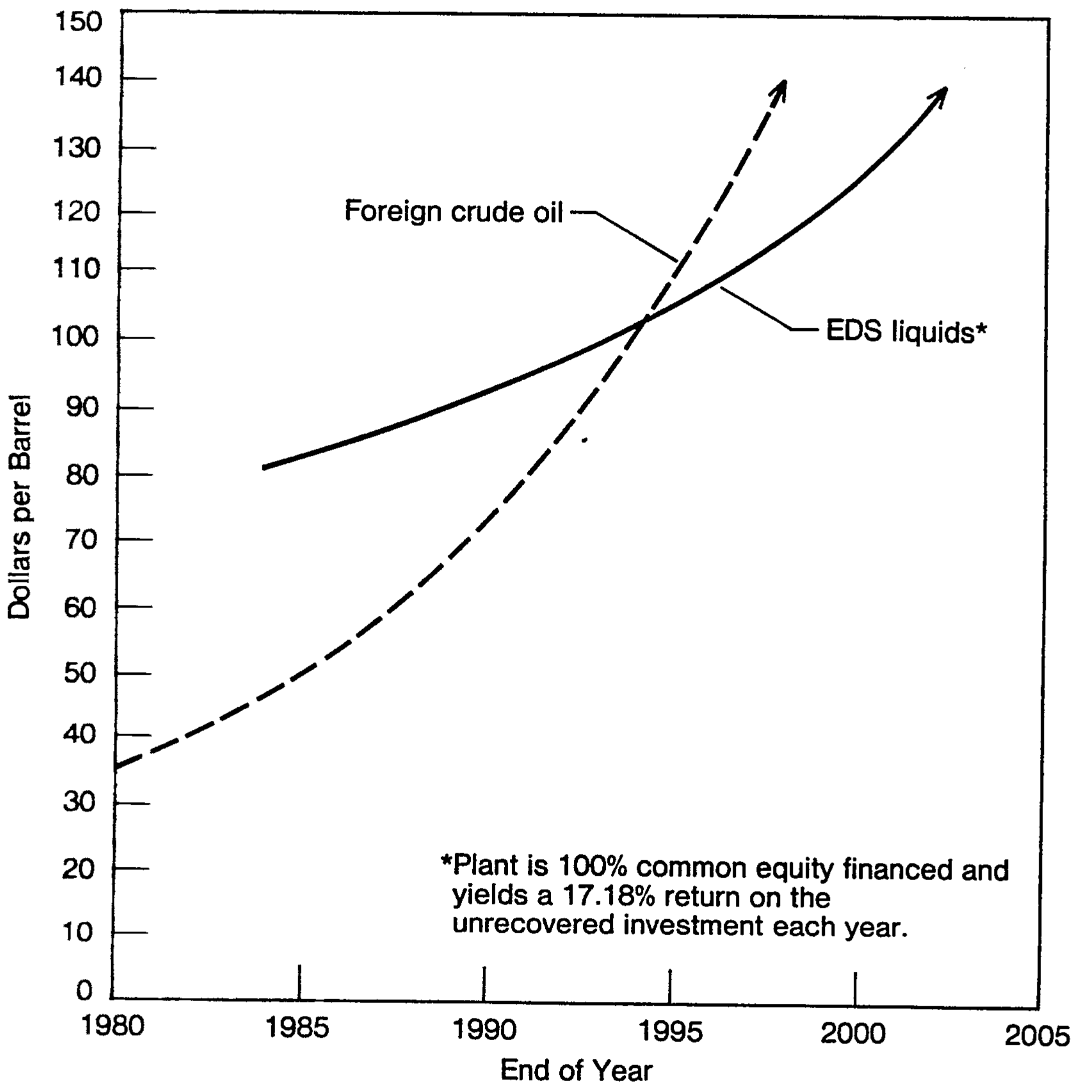

Figure 1. "Year-by-Year" Required Selling Price — Prices are In Current Dollars and Include 8%/Yr Inflation

not be competitive during early years of operation and would be more than competitive in later years, but does not answer the question of overall competitiveness during the EDS plant lifetime.

One way to answer this is to calculate a so-called "levelized price" for the EDS liquids and compare it with a levelized price for crude oil.

A levelized price is one which is the same each year, and allows the producer the same rate of return as that realized if the product were sold at the year-by-year prices. Levelized prices are commonly used in the electric utility industry for making comparisons of alternatives. For those in other industries, it is probably informative to state that the levelized price is the same as the price required for a given rate of return that is usually determined by trial-and-error discounted cash flow calculations. However, the levelized price need not be derived by trial-and-error. It can be derived from year-by-year prices as they are defined above. Its derivation is presented in Appendix I. The result of the derivation is:

$$\text{Levelized Price} = \frac{\text{Present Value of Year-By-Year Revenues}}{\text{Cumulative Present Worth Factor x Annual Production}} \qquad (1)$$

where:
- present value of Year-By-Year Revenues is calculated at the beginning of commercial operation at a discount rate equal to the required return on equity.

- the cumulative present worth factor $= \sum_{1}^{N} \left(\frac{1}{1 + i}\right)^n$,

  with N equal to the economic life of the plant in years and i equal to the fractional required return on equity.

Using equation (1), 8% per year inflation, a 17.18% per year required return on equity and a 25 year plant life, we find:

Levelized Price of EDS Liquids 1984 through 2009 = $93 per barrel

The levelized price of crude oil during the 25 year period beginning in 1984 is:

$$(\$35/\text{Bbl})(1.08)^3(\text{P}) \frac{\left(\frac{1.08}{1.1718}\right)^1 + \left(\frac{1.08}{1.1718}\right)^2 + \ldots \left(\frac{1.08}{1.1718}\right)^{25}}{\sum_{1}^{25} \left(\frac{1}{1.1718}\right)^n (\text{P})}$$

where: $(35)(1.08)^3$ = $44.09 per barrel, the price of foreign oil at the beginning of 1984.

P = production rate - Bbls/year

The numerator of the fraction, when multiplied by the $44.09 beginning price and P yields the present value of the inflating annual revenues.

The denominator of the fraction converts the present value of the inflating annual revenues into a constant annual price.

Solving the above expression yields:

Levelized Price of Foreign Crude Oil = $79 per barrel

At this point, it appears that the EDS liquid may not be competitive in the 1984-2009 time period (except for quality differences between the coal derived liquids and crude oil which are not taken into account in this paper). However, most observers believe foreign crude oil will continue to increase in price at a rate faster than the general rate of inflation. If a real price increase of 2%/year is assumed, the overall rate of escalation at 8%/year inflation would be:

$$(1.08)(1.02) - 1 = 0.1016/\text{yr.}$$

Substituting 1.1016 for 1.08 in equation (1), we get:

Levelized Price of Foreign Crude Oil = $101 per barrel

What does this mean? An EDS plant starting up in 1984 would return more than 17.18% on investment over its 25 year life if the products were sold at the same price as foreign crude.

To this point, it has been shown that although inflation rates can be included in required price calculations, their inclusion results in comparative prices that are substantially higher than today's fuel prices. The prices and their differences are of such high magnitude, they are difficult to accept, to say nothing of the difficulty of explaining them. Another problem with required price calculations as presented above is that various price estimators will undoubtedly use different inflation rates, thus the various resulting prices cannot be compared.

What is needed is a required price which bears a meaningful relationship to today's fuel prices; is calculated taking proper account of future inflation; and is independent of future inflation rates.

Such a price can be calculated and is designated as an "inflation independent price." The phrase "inflation independent" means that if the price is simply allowed to increase with any inflation rate, it will yield the same rate of return as the inflated year-by-year and inflated levelized prices described above.

The inflation independent price is derived in Appendix II. The result of the derivation is:

$$IIP = \frac{\text{Present Value of Year-by-Year Required Revenues}}{\left(\frac{1 + infl}{1 + i}\right)\left(\frac{1 - \left[\frac{1 + infl}{1 + i}\right]^N}{1 - \left[\frac{1 + infl}{1 + i}\right]}\right)(P)\,(1 + infl)^{Yco - Ypd}} \qquad (2)$$

where: IIP = the inflation independent price

infl = the rate of inflation - fraction per year

i = the required return on equity at the inflation rate - fraction per year

N = economic life of plant - years

P = annual production rate

Yco - Ypd = the number of years between the "present day" and commercial operation

and: Present Value of Year-by-Year Revenue Requirements is at the beginning of commercial operation using discount rate i.

Equation (2) yields a price in present day dollars which if indexed to a rate of inflation would yield the same rate of return as the year-by-year or levelized prices at the same rate of inflation.

The proof that IIP is inflation independent must be empirical, for, as will be shown, it is not rigorously inflation independent. But, as also will be shown, it is so close to being rigorously independent of inflation, the designation "inflation independent" is acceptable for practical use.

The empirical proof is provided in Figure 2. Two prices are noted on the drawing--starting prices at the beginning of operations, which increase thereafter with the rate of inflation, and inflation independent prices which are the starting prices de-inflated to the "present day" (mid-1979 for this example).

Two important points are obvious from Figure 2:

- The inflation independent price is essentially the same regardless of the rate of inflation. (The range in the

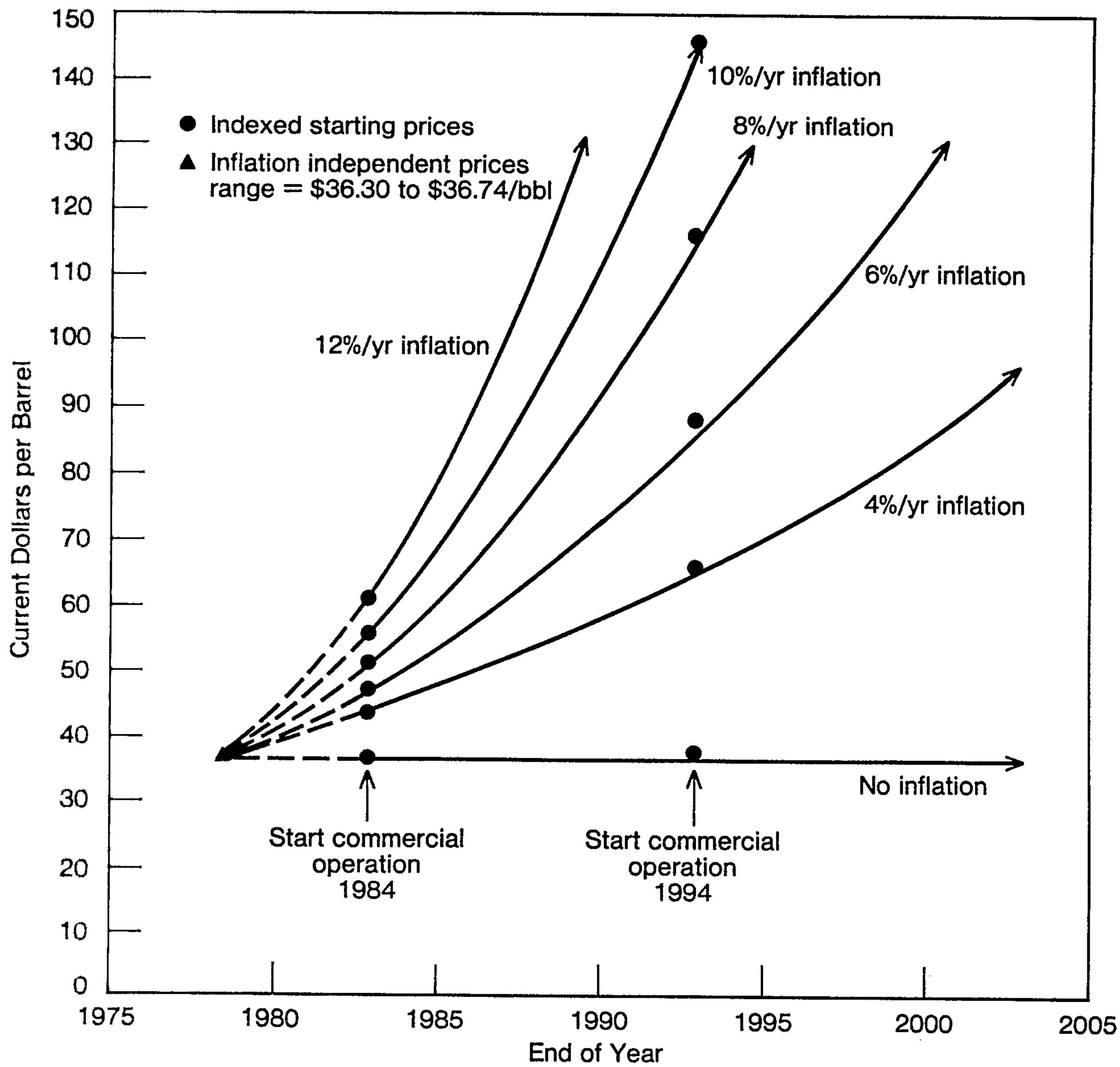

Figure 2. Inflation Indexed Required Prices EDS Liquids

price [about 1%] is because not all costs increase proportionally with the inflation rate. Even so, the range is acceptable from a practical standpoint.)

- The inflation independent price is also virtually independent of the time of start of operations. The slight deviation of the points representing the 1994 start date is caused by the 1% per year increase in the real cost of coal.

To this point, we have seen that an inflation independent price can be derived that is essentially the same regardless of the future rate of inflation assumed in the calculations. This means that a constant dollar analysis using financial parameters prevalent in a non-inflationary period is an acceptable method for expressing synfuel prices. The inflation independent price calculated from the constant dollar analysis is one which can be instantaneously compared with the prices of competing fuels in present day dollars. This allows a more meaningful comparison of prices than prices containing inflation. Also, it removes the confusion from price comparisons when estimated prices contain different inflation rates.

Sometimes, a competitive fuel price is expected to increase at a rate faster than the inflation rate. This is particularly true of foreign crude oil. Most observers believe that its price will continue to increase in real terms. Accordingly, equation 3 allows calculation of an inflation independent required price for a synfuel when competing fuel prices are expected to increase in real terms.

$$IIP = \frac{\text{Present Value of Year-by-Year Required Revenues}}{\left(\frac{1 + esc}{1 + i}\right)\left(\frac{1 - \left[\frac{1 + esc}{1 + i}\right]^N}{1 - \left[\frac{1 + esc}{1 + i}\right]}\right)(P)(1 + esc)^{Yco - Ypd}} \qquad (3)$$

where: IIP = inflation independent price in present day dollars.

esc = (1 + infl)(1 + re) - 1 = fractional rate of escalation of competing fuel price at fractional rate of inflation, infl, and fractional rate of real price increase of competing fuel, re.

i = required rate of return on equity at inflation rate.

N = economic life of plant, years.

P = constant annual production rate.

Yco - Ypd = time between start of commercial operation and the present, years.

and: the present value of year-by-year required revenues is at the start of commercial operation using discount rate i.

Actually, equation (3) is more general than equation (2), for when the rate of real increase in the competing fuel price is zero, the term "esc" becomes "infl."

The price calculated from equation (3) is one which if indexed to the escalating price of the competing fuel would yield the required rate of return on equity. Such prices were calculated for EDS liquids at different inflation rates and at real price increases in competing crude oil of 2%/year and 4%/year. Results are shown in Figure 3, together with the inflation independent price previously calculated at zero rate of increase of the real market price of competing fuel.

It is again obvious that a constant dollar analysis using proper financial parameters is an acceptable method of required price calculation, for the range of the inflation independent price is again quite narrow.

Another important point illustrated in Figure 3 is that if foreign crude oil does increase in real price at only moderate rates, the EDS liquids can be more than competitive, i.e., if the liquids are sold at the same price as foreign oil, the rate of return on equity can be higher than the required return.

Summary

Based on the findings presented:

- It is not necessary to include inflation when calculating required prices, for an inflation independent required price expressed in present day dollars can be calculated. This price is the "real" required price of synthetic fuels.

- Estimated real required prices of intermediate-Btu gas and EDS liquids are as follows:

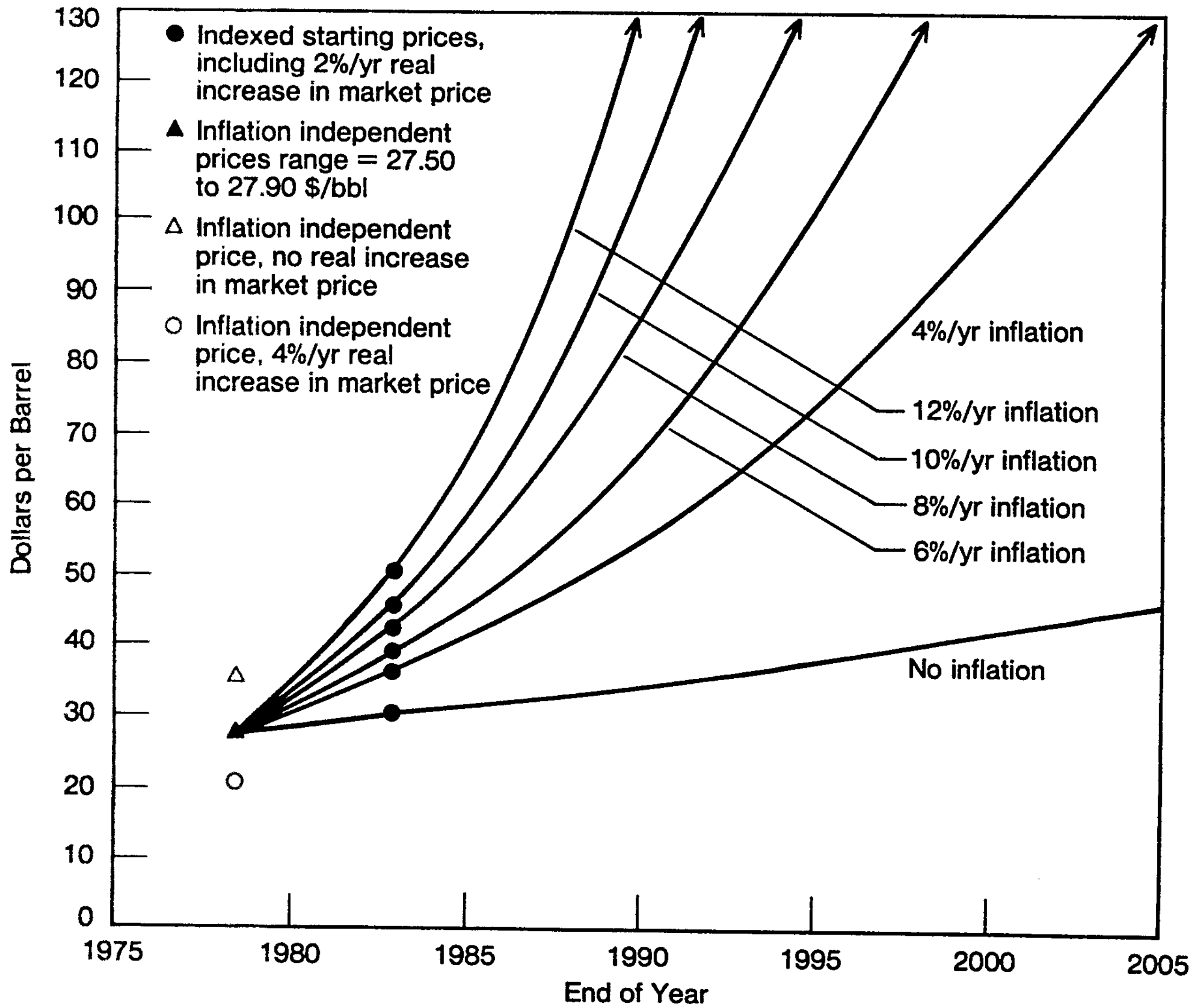

Figure 3. Escalation Indexed Required Prices EDS Liquids

	Real Required Prices of Synfuels Produced From Illinois No. 6 Coal (In Mid-1979$)
EDS Liquid Product:	
0%/Yr. Real Increase in Market Price	31.00* - 36.50† Per Barrel
2%/Yr. Real Increase in Market Price	- 28.00† " "
4%/Yr. Real Increase in Market Price	- 21.00† " "
Intermediate-Btu Gas: ∂	
Using Lurgi Dry Ash Gasifier	- 24.00** " "
Using BGC Slagging Gasifier:	
No Contingency	- 13.00** " "
40 Per Cent Contingency	- 18.20** " "

*Plant financed with 50% equity funds, 50% loan guarantee.

†Plant financed with 100% equity funds.

∂Plants owned and operated by regulated investor owned utilities.

**Prices are per 5.6 million Btu, the higher heating value of a barrel of EDS liquid product.

- Based on the above results, it is seen that intermediate-Btu gas need not depend on subsidies or real increases in fuel market prices to be competitive. It is also seen that development of advanced intermediate-Btu gas technology, such as the British Gas Corporation's slagging gasifier can lead to substantial decreases in costs of intermediate-Btu gas.

Appendix I

Derivation of Levelized Price

Let: R_n = a year-by-year (or unlevelized) revenue requirement in any year n

C_n = cash expenses in year n

D_n = tax depreciation in year n

T = income tax rate

R_l = levelized revenue

CF_n = cash flow in year n

With year-by-year revenues, cash earnings (cash flow) in any year n is:

$$CF_n = R_n - C_n - T(R_n - C_n - D_n)$$

With levelized revenues, cash flow in any year n is:

$$CF_n = R_l - C_n - T(R_l - C_n - D_n)$$

To meet the requirement that levelized revenues yield the same rate of return as the unlevelized revenues,

$$\sum_{1}^{N} (PWF)_n \; [R_n - C_n - T(R_n - C_n - D_n)]$$

must equal:

$$\sum_{1}^{N} (PWF)_n [R_1 - C_n - T(R_1 - C_n - D_n)]^*$$

where: N = Plant economic life, years

$(PWF)_n$ = Present worth factor (end of year) at required rate of return i.

This requirement can be expressed as:

$$\sum_{1}^{N} R_n (PWF)_n - \sum_{1}^{N} C_n (PWF)_n - T\sum_{1}^{N} R_n (PWF)_n$$

$$+ T\sum_{1}^{N} C_n (PWF)_n + T\sum_{1}^{N} D_n (PWF)_n$$

$$= R_1 \sum_{1}^{N} (PWF)_n - \sum_{1}^{N} (C_n)(PWF)_n - (T)(R_1) \sum_{1}^{N} (PWF)_n$$

$$+ T\sum_{1}^{N} C_n (PWF)_n + T\sum_{1}^{N} D_n (PWF)_n$$

Cancelling terms, this reduces to:

$$\sum_{1}^{N} R_n (PWF)_n - T\sum_{1}^{N} R_n (PWF)_n$$

$$= R_1 \sum_{1}^{N} (PWF)_n - (T)(R_1) \sum_{1}^{N} (PWF)_n$$

*For it can be shown that return on unrecovered equity of i per year is a discounted cash flow return of i per year.

Factoring:

$$(1 - T) \left[\sum_{1}^{N} R_n (PWF)_n\right] = (1 - T) (R_1) \sum_{1}^{N} (PWF)_n$$

Reducing and rearranging:

$$R_1 = \frac{\sum_{1}^{N} R_n (PWF)_n}{\sum_{1}^{N} (PWF)_n}$$

Or, in words, levelized revenue is the present value of the unlevelized revenues divided by the cumulative present worth factor. The levelized price is simply the levelized revenue divided by a constant annual production rate.

Appendix II

The inflation independent price is derived as follows:

Let R_o = Annual revenue required at beginning of commercial operation at a price which increases by the rate of inflation.

R_n = A year-by-year revenue requirement in any year n

C_n = cash expenses in year n

D_n = tax depreciation in year n

T = income tax rate

CF_n = cash flow in year n

infl = inflation rate, fraction per year

i = required return on investment, fraction per year at the inflation rate

With year-by-year revenues,

$$CF_n = R_n - C_n - T(R_n - C_n - D_n)$$

If revenue at beginning of commercial operation is R_o, then revenue in any year n is $R_o(1 + \text{infl})^n$ and

$$CF_n = R_o(1 + \text{infl})^n - C_n - T\ [R_o(1 + \text{infl})^n - C_n - D_n]$$

To meet the requirement that the rate of return when using R_o as the beginning revenue be the same as that when using the year-by-year prices,

$$\sum_{1}^{N}(PWF)_n[R_o(1 + infl)^n - C_n - T(R_o[1 + infl]^n - C_n - D_n)]$$

must equal:

$$\sum_{1}^{N}(PWF)_n[R_n - C_n - T(R_n - C_n - D_n)]*$$

where: N = Plant economic life, years.

$(PWF)_n$ = Present worth factor (end of year) at required rate of return i.

This requirement can be expressed as:

$$R_o\sum_{1}^{N}(PWF)_n(1 + infl)^n - \sum_{1}^{N}(PWF)_n(C_n) - (T)(R_o)\sum_{1}^{N}(PWF)_n(1 + infl)^n$$

$$+ T\sum_{1}^{N}(PWF)_n(C_n) + T\sum_{1}^{N}(PWF)_n(D_n)$$

$$= \sum_{1}^{N}(PWF)_n(R_n) - \sum_{1}^{N}(PWF)_n(C_n) - T\sum_{1}^{N}(PWF)_n(R_n)$$

$$+ T\sum_{1}^{N}(PWF)_n(C_n) + T\sum_{1}^{N}(PWF)_n(D_n)$$

*For it can be shown that return on unrecovered equity of i per year is a discounted cash flow return of i per year.

Cancelling terms, this reduces to:

$$R_o \sum_{1}^{N} (PWF)_n (1 + infl)^n - (T)(R_o) \sum_{1}^{N} (PWF)_n (1 + infl)^n$$

$$= \sum_{1}^{N} (PWF)_n (R_n) - T \sum_{1}^{N} (PWF)_n (R_n)$$

Factoring both sides:

$$(1 - T)[R_o \sum_{1}^{N} (PWF)_n (1 + infl)^n] = (1 - T)[\sum_{1}^{N} (PWF)_n (R_n)]$$

Cancelling and rearranging:

$$R_o = \frac{\sum_{1}^{N} (PWF)_n (R_n)}{\sum_{1}^{N} (PWF)_n (1 + infl)^n}$$

Since $PWF_n = \frac{1}{1 + i}^{\,n}$

$$R_o = \frac{\sum_{1}^{N} (PWF)_n (R_n)}{\sum_{1}^{N} \left(\frac{1 + infl}{1 + i}\right)^n}$$

Or,

$$R_o = \frac{\text{Present Value of Year-By-Year Required Revenues}}{\left(\frac{1 + infl}{1 + i}\right)\left(\frac{1 - \left\{\frac{1 + infl}{1 + i}\right\}^N}{1 - \left\{\frac{1 + infl}{1 + i}\right\}}\right)}$$

The inflation independent price (IIP) is calculated from R_o as follows:

$$IIP = \frac{\text{Present Value of Year-By-Year Required Revenues}}{\left(\frac{1 + infl}{1 + i}\right)\left(\frac{1 - \left\{\frac{1 + infl}{1 + i}\right\}^N}{1 - \left\{\frac{1 + infl}{1 + i}\right\}}\right)(P)\,(1 + infl)^{Yco - Ypd}}$$

where: P = Constant annual production rate.

Yco - Ypd = Time between start of commercial operation and the present day, years.

SYNTHETIC FUELS AND THE TOTAL COST OF OIL IMPORTS

Bernard S. Lee

SYNTHETIC FUELS AND THE TOTAL COST OF OIL IMPORTS

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Today, I would like to examine some basic policy and economic issues which will influence the development and deployment of a synthetic fuels industry. The three areas which I have selected for analysis are (1) the overall technological basis of synthetic fuels, (2) the cost of synthetic fuels relative to imported oil, and (3) the deployment schedule necessary for a synthetic fuels industry to meet projected production goals.

The Technological Basis For Synthetic Fuels

The technology of synthetic fuels is, in my opinion, the most manageable and least troublesome of the factors which influence development of a synthetic fuels industry. Although sometimes it seems that our progress has been agonizingly slow, a look back ten or fifteen years from the present indicates a healthy growth pattern. Much of the growth has occurred in other countries, and provides a good example of what can be accomplished given the dedication to meet national goals and the will to proceed despite formidable obstacles. I cite as examples the development of the Canadian tar sands, the expansion of synthetic fuels production capability in South Africa, and the alcohol production program in Brazil.

The lag in the United States is not due to any lack of effort on the part of individual companies or to lack of technology. The gas utility industry, in particular, has been trying since 1972 to build coal gasification plants using commercially available Lurgi technology. To date, although a dozen or more projects have been proposed, none have been implemented. Several advanced processes are ready for demonstration. Again, construction has been delayed. The same scenario is evident in the efforts to get started on liquid fuels from coal and oil shale and combined cycle electric power generation based on coal gasification.

Fortunately, this logjam started breaking up in the last year. The Great Plains high-Btu coal gasification plant, based on Lurgi technology, may get started this year even though the legal issues impeding the proposed funding method are not resolved. The Department of Energy and the Memphis Gas Light and Water Division are jointly funding a large medium-Btu demonstration plant based on IGT's U-GAS process to provide the utility with industrial fuel gas, with completion scheduled for 1984. Construction of one or more high-Btu gas demonstration plants may be initiated in 1981. The SRC-I and -II programs are well under way. The electric power industry is proceeding with a large demonstration program on combined cycle power generation based on use of the Texaco gasifier. The development of western oil shale is being accelerated. Exxon Corporation has purchased a controlling interest in the Colony oil shale project with the goal of putting a 46,000 Bbl per day plant on stream in 1985 using the Tosco process. Union Oil Company has announced its intention to invest $130 million in a 9,000 Bbl per day pilot plant in Colorado.

The Synthetic Fuels Corporation has been established to aid in the commercial application of existing and advanced technologies. A wide variety of advanced technologies are under investigation, as is evident from the many excellent papers presented at this meeting. All these developments show we are making some real progress.

The Cost of Synthetic Fuels Relative to Imported Oil

A major issue which has impeded development of a synthetic fuels industry is the argument that they cannot compete with conventional fuels on a price basis. This may have been true in the past, but even then, the reasoning was suspect because the comparison was often made using conventional fuel prices which, by regulation, were held at a level below their true market value. The recent sharp increases in world oil price, combined with the phased deregulation of U.S. conventional crude oil and natural gas, have made synthetic fuels much more attractive from an economic viewpoint.

However, there is a more basic economic problem which must be recognized in comparing natural and synthetic fuels. There is practically unanimous agreement that overdependence on imported oil is the cause of many of our current problems. The price of this imported oil is high — about $35-$37 per barrel at present — and rising steadily. The problems arise from the fact that the posted price of imported oil does not truly reflect the actual cost to the United States. By actual cost, I mean not only the posted price, but the effect of imported oil on inflation, employment and national security. A little over a year ago, we at IGT started considering these additional costs of imported oil[1]. At the time there were only two or three very generalized estimates available on the external costs of a barrel of imported oil, ranging from $10 to $100 per barrel[2,3,4]. We decided to try to quantify these costs by attempting a more explicit estimate of the major external costs associated with oil imports.

Before proceeding, let me define the meaning and role of externalities. When a cost or benefit is incurred by someone other than the producer or buyer, it occurs outside the market transaction and is thus an externality. An external cost occurs when part of the cost of producing or using a good must be paid by someone other than the firm which produced it or the individual who consumed it. Prices, thus, do not always reflect all the costs incurred in producing or even using a product. For example, manufacturers poured smoke relatively freely into the air when they did not have to pay the cost of environmental clean-up. Externalities create the case for government intervention to either set standards to end the externalities or to set payments on the market transaction such that those who incur external costs are compensated or those who receive external benefits contribute in a market transaction.

The consumer of imported oil is largely spared the external costs, and the external costs are not felt by the consumer when he makes his market transaction. Thus, the cost of imported oil is lower than if the cost reflected the associated externalities of inflation, unemployment, and national risks. This causes a biased cost comparison leading the consumer to overconsume oil imports.

Table 1 shows the latest results of our continuing work in this area. The components of the externalities associated with reducing oil imports are combined and joined with the direct benefit of lower oil imports. The study is based on a reduction of oil imports into the United States by 500,000 barrels per day, and the benefits per barrel would be essentially unchanged for reductions in oil imports much higher than the base case.

The direct benefit is, of course, the base price of imported oil, which is assumed to increase at 2% per year in real terms. The United States would have an improved trade balance with consequent currency appreciation and lower inflation if oil imports were lowered. As demand on the world market slackens due to reduced demand by the U.S., lower oil prices will result. Additionally, there will be added real output in the economy due to the decreased dollar leakage to foreign countries to pay for the imported oil. The final external benefit — improved national security — is the most difficult to estimate. In our study, we assumed that this benefit can be conservatively approximated by the annual levelized value of the lost economic costs of about $14.67 per barrel even with a one billion barrel reserve, due to the reduction in gross national product caused by an embargo, and then reduced to $13.50 per barrel by taking into account the lower cost of maintaining the strategic petroleum reserve due to the reduction in imports of 500,000 barrels per day.

Another approach, equally difficult to quantify, is to consider the cost per barrel of imported oil of that portion of the national defense budget which must be allocated to protection of our foreign sources of supply. For example, if in the future it is necessary to increase the national defense budget by 20% over the current budget of $139 billion in order to protect our foreign sources of supply, the cost again would be about $12 per barrel. In any event, we believe that this external benefit, along with the other externalities estimated, tends to be on the conservative side. If the external benefits of reducing oil imports are added to the direct benefit, then the total per barrel benefit of large scale reductions in oil imports will be on the order of $80 to $110 per barrel over a three-year period, or an average of about $16.37 per million Btu. In comparison, recent estimates of the costs of synthetic fuels from coal and oil shale are in the range of $23 to $64 per barrel of oil equivalent, or $4.00 to $11.00 per million Btu (1979 dollars). (Table 2.) On this basis, synthetic fuels are a bargain compared to imported oil.

Table 1. BENEFITS FROM REDUCTION OF OIL IMPORTS BY 500,000 BBLS/DAY

	Year 1	Year 2	Year 3
		1980$/bbl	
Direct Benefit	$37.00	$37.74	$38.49
External Benefits			
Oil Price Effect	12.32	17.71	18.98
Inflation Effect	11.19	20.41	21.18
Employment Effect	6.60	12.70	17.13
Security Effect	13.50	13.50	13.50
Sub Total	43.61	64.32	70.79
Total Benefit	80.61	102.06	109.28

Table 2. HIERARCHY OF SUPPLEMENTAL ENERGY SOURCES BY COST

Supplemental Sources	Estimated Price at Point of Production $(1979)/$10^6$ Btu
High-Btu Gas From Coal (2nd Generation)	4.00-5.50
Medium-Btu Gas From Coal (1st Generation)	4.00-5.50
Solvent Refined Coal (Solid)	4.00-5.50
Crude Shale Oil (All Processes)	4.00-6.00
High-Btu Gas From Coal (1st Generation)	5.00-6.00
Low Sulfur Heavy Fuel Oil From Coal	5.00-6.00
Distillate Fuel Oil From Coal	6.00-7.00
Methanol From Coal	6.00-9.00
Gasoline From Coal	8.00-11.00

Source: Gas Research Institute

After considering the external costs of oil imports, the obvious next question concerns the size of the externalities associated with synthetic fuels production. In the last decade, the United States passed a series of environmental protection laws, with the result that some of the external costs are now part of the firm's production costs and as such are reflected in the market price or the direct cost. For example, the price of coal from strip mines now includes a charge to cover land reclamation costs. Land reclamation has been made part of the firm's cost by public policy; the externalities, in the language of the economist, have been internalized. For many new technologies, the externalities associated with air, water or land pollution have been made part of the production costs. Thus, the United States has seen the direct costs of these sources rise rapidly, while the external costs have largely disappeared. However, some external costs still may exist with respect to coal, water, capital, environmental and health areas. These remaining externalities of synthetic fuels are the subject of ongoing studies at IGT. Preliminary results indicate that even if the remaining foreseeable externalities are added to the cost of SNG from coal, the total cost will still be about $30 per barrel of oil equivalent lower than imported oil with its external costs. Thus, using these economic measures, synthetic fuels will still be a bargain compared to imported oil.

Deployment of a Synthetic Fuels Industry

The third major area requiring consideration is the deployment of a synthetic fuels industry. In July of 1979, President Carter proposed a goal of displacing 2.5 million barrels per day of oil imports by synthetic fuels and unconventional gas production and an overall reduction of 4.5 million barrels per day from these sources plus heavy oil and various conservation measures. The program is ambitious, but, in my opinion, achieveable if the nation approaches this program with a total commitment and mobilization of its human, technical and financial resources. The two mainstays of a realistic energy policy are expanded energy supply and increased energy conservation. The nation needs both. Those who claim that conservation alone can solve the energy problem for the long term mislead the public and do themselves and the nation irreparable disservice.

It is imperative to begin immediately the energy supply options, especially synthetic fuels, because it takes long lead-times plus large capital to develop these options. The gaining of several years of time by concerted action now can more than pay the cost of development, given the true cost of imported oil and recognition of the fact that it will cost even more in the future.

Although the President's program deals with large-scale commercial deployment of various technologies to achieve a substantial oil import reduction, it is also imperative that well-planned programs for research, development and demonstration be continued to maintain the flow of technological innovations and improvements. The President's program establishes the mechanism for launching the synthetic fuels industry on a broad front. This vital step in no way diminishes, and in fact demands greater emphasis on, the need for solid research and development to support the massive commercialization effort.

The supply segment of the President's program contains two major elements which I wish to address. These are: (1) the development of 2.5 million barrels per day (MMB/D) of oil substitutes with liquids and gases from coal, peat, oil shale, biomass, and unconventional gas; and (2) the requirement to cut utility consumption of oil by 0.75 million barrels per day.

When the President's program was announced last year, I outlined a schedule that would achieve these targets[5]. Since that time, the Synthetic Fuels Corporation has been formed, with the preliminary goal of 500,000 barrels per day oil equivalent of synthetic fuels production by 1987 and 2 million barrels per day by 1992. Although this production schedule is about two years later than the President's original plan, the total quantity of synthetic fuels is about the same. Since the present SFC production targets have not been defined individually, I believe my earlier analysis is still applicable, with all the dates pushed back two years.

My program would achieve the target goals through two waves of deployment. The first wave consists of deploying several commercial plants using currently-available technologies, while simultaneously deploying demonstration plants for a number of advanced technologies to establish their commercial viability. The second wave will then come in the late 1980's for deploying commercial plants based on demonstrated advanced technologies. Those first-wave commercial plants will continue to be feasible because of the cost escalation during the time period while advanced technologies are being demonstrated. These plants will also provide a real reference for production cost, performance and environmental data. The second-wave commercial plants will be more efficient and economical than the first wave and will be the basis for the competitive growth of the synthetic fuels industry.

In my program, I have indicated the number of demonstration and commercial-size plants needed as well as when and where these should be deployed. The number of plants represents the number of commercial-size units. Some locations may support more than one unit. Similarly, a demonstration plant can be expanded to a commercial-size plant at the same site. Specifically:

- As to the split between gaseous and liquid fuels, since (1) gaseous fuels can be substituted directly for oil in essentially all stationary applications, (2) gas represents a finished product of high form value, and (3) the cost of gas production is lower than that of liquids, IGT recommends that at least half of the target goal be synthetic gases.

- IGT recommends that the fossil resources in the East be strongly emphasized because:

  a. the recoverable bituminous coal resource in the East is at least as great as that of lignite or subbituminous coal in the West, and similarly for Eastern shale relative to Western shale.

b. water is much more available in the East.

c. markets are much closer to the points of production in the East.

d. the skilled manpower pool and manufacturing resources are greater in the East.

- To fully utilize coal, both high- and medium-Btu gasification plants should be on-stream. Medium-Btu gas plants can economically serve industrial users concentrated within a relatively small radius, while high-Btu gas plants can be connected to the existing natural gas transmission and distribution network to serve residential, commercial and industrial users.

- In the area of oil shale, the President's target can be achieved by simultaneously developing shale resources both in the West and in the East to produce both high-Btu gas and liquids. The Eastern shale resources, in addition to being close to the population centers, with much more water availability, have a more favorable shale chemical composition that minimizes leaching, and should be developed via advanced hydrogen retorting technologies.

- The President's targets for biomass and unconventional gas appear reasonable.

- To achieve a 50% reduction of oil use in utility boilers, a logical approach is to replace oil with clean fuel gas from Eastern coal, since many of these boilers are concentrated in the East. At least half of the President's target should be met by making use of advanced gasification and combined-cycle technology that not only provides clean fuel but also higher efficiency of power generation.

The detailed deployment schedule of the various synfuels resources is outlined in Table 3. According to this plan, by the late 1980's after the first-wave deployment, we could have a synthetic fuels production capacity of 520,000 barrels per day of oil equivalent, very close to the current target of 500,000 barrels by 1987. The total after the second-wave deployment would be 2,050,000 barrels per day of oil equivalent of synthetic fuels, again very close to the current target of 2,000,000 barrels per day by 1992.

Of the total after the second-wave, as indicated in Table 4, synthetic gases, both high- and medium-Btu, to provide oil substitutes and to reduce the use of oil in utility boilers would amount to 1.15 MMB/D oil equivalent. The total synthetic liquids from coal and oil shale would amount to 0.9 MMB/D oil equivalent. The capital investment, in 1979 dollars, excluding mining investment, would be about $90 billion for synthetic fuels production. This figure is very close to the planned funding of the Synthetic Fuels Corporation.

Table 3. IMPLEMENTATION OF TWO ELEMENTS OF PRESIDENT CARTER'S PROGRAM

A) Target: 2.5 MMB/D oil substitutes with gases and liquids from coal, peat, oil shale, biomass, and unconventional gas by 1992

Oil Equivalent, MMB/D

1) Coal Gases and Liquids 1.25

- o 15 high-Btu gas commercial-size plants, 6 in West, 9 in East, each 250 X 10^9 Btu/D
  Total 0.6 MMB/D
  - i) Deploy now 3 Lurgi commercial plants in West
  - ii) Deploy now 3 demo plants in East for advanced technologies
  - iii) Deploy in 1988 using advanced technologies:

    3 commercial plants in West

    9 commercial plants in East (including 2 using peat)

- o 5 medium-Btu industrial fuel commercial plants, each 100 X 10^9 Btu/D
  Total 0.1 MMB/D
  - i) Deploy now 2 demo plants in East
  - ii) Deploy in 1987, 5 commercial plants in East

- o 11 coal liquids plants, each 50,000 B/D
  Total 0.55 MMB/D
  - i) Deploy now 3 SASOL-type plants in West
  - ii) Deploy now 3 demo plants for advanced technologies, 2 in East, 1 in West
  - iii) Deploy in 1988 using advanced technologies:

    3 commercial plants in West

    5 commercial plants in East

Oil Equivalent, MMB/D

2) Oil Shale — 0.4

- o 7 shale liquids commercial plants, 5 in West, 2 in East; 1 Eastern shale, high-Btu gas commercial plant

  i) Deploy now 5 Western shale liquids commercial plants, each 50,000 B/D
  Total 0.25 MMB/D

  ii) Deploy now 1 Eastern shale demo plant

  iii) Deploy in 1988, 2 Eastern shale liquids commercial plants, each 50,000 B/D, and 1 Eastern shale, high-Btu gas commercial plant, 250 X 10^9 Btu/D
  Total 0.15 MMB/D

3) Biomass — 0.1

4) Unconventional Gas — 0.75

Production Capacity Total 1992 — 2.5 MMB/D

B) Target: <u>0.75 MMB/D oil reduction in utility boilers by 1992</u>

1) Coal Gasification in Combined Cycle

20 commercial plants, each 100 X 10^9 Btu/D or 500 MW — 0.4

i) Deploy now 3 demo plants in East

ii) Deploy in 1988, 20 commercial plants, mostly in East

2) Other Oil Displacements, e.g., Fluidized Coal Combustion, Direct Coal Combustion with Stack Gas Cleanup — 0.35

Reduction Total — 0.75

Table 4. SYNFUELS PLANT DEPLOYMENT AFTER SECOND WAVE IN 1992

	Eastern States	Western States	Energy Output 10^9 Btu/Day	10^6 bbls/Day
Coal-to-SNG	7	6	3250	0.5
Peat-to-SNG	2	-	500	0.1
Coal-to-Fuel Gas	5	-	500	0.1
Oil Shale-to-SNG	1	-	250	0.05
Oil Shale-to-Oil	2	5	-	0.35
Coal-to-Liquids	5	6	-	0.55
Coal-to-Combined Cycle (Barrels of Oil Displaced)	14	6	2000	0.4
Other Power Plant Displacements				0.35
Biomass				0.1
Unconventional Gas				0.75
			TOTAL	3.25

A massive commitment of financial and human resources will be necessary to carry out this ambitious program. Since time is short, action must start immediately to resolve the regulatory and institutional constraints. A rational and workable balance between environmental and energy goals must be established and maintained. The adversary stance of government and private industry must be reversed to one of mutual cooperation. If we can accomplish these objectives and start developing a synthetic fuels industry, the benefits will increase commensurately with the commitment. The security of energy supply will increase, our national defense posture will be strengthened, the price rise of imported energy will be moderated, and the U.S. can formulate and implement national and international policy free of the constraints imposed by overdependence on foreign energy supplies.

In summary, we have a large and rapidly expanding technological base for synthetic fuels production. The true cost of synthetic fuels to the nation is lower than the cost of imported oil. Given a workable government-industry relationship, a substantial synthetic fuels industry can be deployed. Let's get on with the job.

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"THE PROBLEMS AND REWARDS IN BUILDING NATIONAL SELF-SUFFICIENCY IN ENERGY"

Mr. Johannes A. Stegmann

"THE PROBLEMS AND REWARDS IN BUILDING NATIONAL SELF-SUFFICIENCY IN ENERGY"

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Republic of South Africa

Mr. Chairman:

I am highly honoured to have been invited to speak at this banquet to such a distinguished audience. I have selected as the main subject of my talk, South Africa's experience in the creation of a synthetic fuels industry. Apart from some general comments on the technical side of the industry, I have decided to focus mainly on how we in South Africa structured a suitable economic framework for the truly large scale introduction of synthetic fuels into the economy.

I have been following closely the growing enthusiasm for synfuels in the United States in recent years. I therefore share in your delight that a basic statutory framework has now been created for the establishment of such an industry and that production targets have been set. It is not for me to say how you in the United States should deal with the peculiar problems and challenges which accompany the setting up of a synfuels industry in your country. I am sure that conditions here differ in many respects from those prevailing in my country. I would nevertheless like to share with you some of the experiences we have had in striving towards self-sufficiency in the field of liquid fuels. I hope my comments will stimulate constructive discussion on how to facilitate the rapid and effective introduction of a synthetic fuels industry in the United States.

On one point there can be no disagreement whatsoever: it is imperative for the future well-being of not only the United States, but of Western civilization as we know it, that the United States should drastically reduce its dependence on imported oil in the next decade or so. There is a distinct limit to the economic resilience of industrialised countries - leave alone the less fortunate countries - to absorb the ever-increasing costs of imported energy, or more specifically of imported oil.

Synfuels do not provide the only answer, but must surely be an indispensable component of the energy strategy of countries such as the United States, Australia and South Africa with extensive coal and other fossil fuel resources which can be exploited for really large scale synfuel production. In countries and climates where it is economically competitive with the liquefaction of fossil fuels, synfuel production from biomass may also be able to make a significant contribution to energy self-sufficiency.

South Africa started its oil-from-coal industry with the construction of Sasol One shortly after the Second World War, albeit on a relatively modest scale. It was conceived as a commercial proposition by a private mining group who had started with the production of transport fuels from a limited deposit of torbanite shale before World War II. However, they could not raise the necessary finance to establish the proposed oil-from-coal plant. Sasol was founded and took over the project in 1950, but still as an out-and-out commercial venture, even though it was at that time effectively wholly owned by the Government.

Today, private investors hold 65%, which will shortly rise to 70% of the shares of the parent company in the Sasol group. This would not have been possible if Sasol One, despite grave initial technical difficulties, had not turned out to be a great commercial success. Already in the years before international oil prices started their rapid escalation, the company was steadily increasing its profits from year to year.

Originally Sasol One's production made only a modest contribution to South Africa's liquid fuels supply, but it laid a sound foundation for the rapid expansion of our synthetic fuels industry once oil prices started their upward spiral. Prior to that, during its first 20 years of operation, Sasol experienced relatively constant prices for its products. Construction costs on the other hand escalated year by year and because oil-from-coal is a capital intensive industry, expansion of the industry would have been uneconomic during that period.

During the 1960's, however, Sasol not only turned the first plant into a fully viable operation, but continued with intensive research and development work to improve and refine the - Sasol process of indirect liquefaction in the firm belief that the time would come when the construction of new plants would be a profitable proposition once again. During all this time research and development work on synfuels elsewhere, and particularly on direct liquefaction, was at a standstill.

The start of the OPEC price hikes in the early 70's excited interest in synfuels once again and as you all know, a good deal of new research work has since been initiated, particularly on direct liquefaction. Sasol itself has also conducted extensive research on direct liquefaction including successful pilot plant work over a period of more than 9 years.

Nevertheless, there is no doubt that for the present and for some years to come, the Sasol process is still the only fully proven process that can be applied with confidence to produce from a very wide range of brown and hard coals, all the liquefied fuels that are normally produced from natural petroleum, including LPG, gasoline, jet fuel and other kerosenes, diesel fuel and light furnace oil.

Methanol synthesis is of course also commercially proven but cannot be used as such in vehicles that are on the road today. Processes for converting methanol into gasoline are being developed, but the production of diesel and other middle distillates still seems to be little more than a research objective.

The oil price explosion of November 1973 forced us in South Africa to take a serious look once again at the economics of a new oil-from-coal project. By November 1974 the decision had been taken to build Sasol Two, an updated and much larger plant than Sasol One, making use of the results of more than 20 years of research and development on the original processes.

This project was conceived and approved as a commercial venture competing with products refined from imported crude oil at OPEC prices and enjoying only a relatively small tax advantage over products refined from crude oil. The bulk of the finance is being contributed by the South African Government, essentially in the form of an equity stake, leaving 20% as loan capital.

The project was announced at the end of 1974 and the site selected in May 1975. A check cost estimate was made in October 1975 which was within 10% of the order of magnitude estimate made in February 1974, allowing for escalation. The October 1975 estimate was R1 900 million at 1975 prices, and the end-of-job cost was estimated also in October 1975 to be R2 500 million or $3 250 million at the current exchange rate.

I am pleased to say that the construction cost of the project upon completion is within the October 1975 estimate, which I dare say is a feather in the cap for the engineers of Sasol and our major contractors. Moreover, construction has been completed on schedule. As a matter of fact, two years ago the date originally planned for mechanical completion of the total plant had been brought forward nine months from April 1981 to mid 1980.

South Africa would probably not have proceeded with a third Sasol until the mid 1980's if the effects of the Iranian crisis had not been thrust upon us at the end of December 1978. To see this statement in perspective, one has to realize that a project the size of Sasol Two places high demands on the financial and economic resources of a country the size of South Africa.

Translated to the size of the American economy, one Sasol Two-type plant represents for South Africa an investment in synfuels equivalent to more than $200 billion in the United States, and two such plants, more than $400 billion, all at 1980 price levels. Comparing this with the amount of money that has recently been appropriated in support of synfuels in the United States, I think you will agree that South Africa can justifiably claim to be leading the world in its total commitment to synthetic fuel production.

In December 1978 we were thus confronted through no choice of our own, with the very difficult decision whether to proceed with a third Sasol project. With all the difficulties which you have had with a "fast track" in this country recently, I think you will be interested to hear something about our sprint in South Africa.

The first thought of constructing Sasol Three came late in December 1978. A preliminary but reliable report on all the essential parameters including cost of construction, economic viability and an overall financing scheme as well as a time schedule was available by January 5, 1979, followed by a definitive report and recommendation to South Africa's Energy Policy Committee on January 19.

A decision to proceed with the project was taken by the Government late in January and it was formally announced on February 22, 1979. Today, less than 18 months after the go-ahead was given, physical construction on the site has already passed the 25% completion mark.

I would now like to expand on the South African synfuels policy which permitted Sasol Two and Sasol Three to be undertaken as commercial ventures. I also assume that you would like to know how we arranged the financing of these projects and the impact that the introduction of two such large projects in a relatively short period of time had on the economy of the country.

In South Africa, liquid fuels and in particular transport fuels, have always been priced at the equivalent cost of refining crude oil imported at ruling international prices. Products from synfuel projects, therefore, effectively have to compete with OPEC prices ruling from time to time, barring a moderate tax advantage equivalent to approximately $5,00 per barrel of crude which the industry enjoys. In other words, all synfuel producers using indigenous raw materials qualify for a tax advantage equivalent to approximately $5,00 per barrel, compared with refiners processing imported crude oil.

This means that Sasol Two and Sasol Three receive no other subsidies or assistance from the Government or anybody else other than the limited tax advantage. The production of alcohol from biomass for use as motor fuel naturally also qualifies for the $5,00 tax advantage.

Your reaction may be that a gap of $5,00 per barrel between OPEC oil prices and coal-based synfuels appears to be very small indeed. On this score I have some comments to make which will no doubt interest you.

There are a number of factors favouring synfuel production in South Africa.

- First of all, there are suitable coal fields in the immediate vicinity of our main industrial area. The basic infrastructure for the establishment of synfuel plants therefore already exists and the market is close by.

- Secondly, nature has given us relatively favourable geological conditions permitting highly mechanised extraction techniques so that coal can be delivered to the synfuel plants at Secunda at a cost - including return on capital - of less than $10,00 per ton, based on 1980 price levels.

- Thirdly, because the industry and its natural market are remote from the coast, it enjoys some transport protection against products refined from imported crude oil.

But what is even more important than these inherent economic advantages enjoyed by us in South Africa, is that we realised a long time ago that in trying to close the gap between the cost of synfuels and international oil prices, one is confronted with a moving target which can more effectively be attacked sooner rather than later. Let me elaborate.

The classic method of project evaluation uses discounted cash flow techniques which place a very high premium on cash flow during the early years of a project and very little on cash flow during later years. This technique can be quite inappropriate when evaluating the economics of highly capital intensive synfuel projects, particularly if the calculations are based on frozen cost and price levels.

The only realistic approach is to calculate the cash flow and profit position of the project from year to year for a number of scenarios using in each case different assumptions of what might happen to cost and product price levels during the anticipated economic life of the project.

With such highly capital intensive projects, cash operating costs are relatively low. Product price increases, once the capital investment has been made, will therefore tend to gear into profits rapidly even if cost inflation should be of the same order as product price inflation. Surely nobody here tonight is going to argue about the inevitable upward trend of international oil prices during the next decade or two. With capital intensive synfuel projects, the nature of the beast is therefore relatively lower profit potential in early years and relatively higher profit potential in later years, which will more than compensate for any initial profit lag.

The conclusion is obvious. In this game, those who have the courage and conviction to take the first plunge, will reap the highest rewards. This is a much more viable approach than ineffective attempts to try and hit a moving target which hopefully will come closer but in reality tends to recede all the time.

For as far ahead as I can see, I cannot visualise any joy for those who want to wait with synfuel projects until international oil prices are at a level which will give a very high return on investment already in the first year of full production. Such thinking may lead to the painful discovery of the meaning of the words "he who wants all, will lose all".

The practical approach which South Africa has adopted, and which I believe is feasible in all countries contemplating high capital investment synfuel programmes based on solid fossil fuels, is:

- for the investor to set a relatively modest but still commercially acceptable minimum return objective for the first years of production;

- for the Government to support the industry to the extent that may be required to bridge the remaining gap between the investor's price expectation and the prevailing oil price (in the case of South Africa it was \$5,00 per barrel of crude oil equivalent);

- for the investor to take the plunge and to await the bonanza which must come.

A case in point is Sasol One which was built in the 1950's, expanded in the 1960's and which is at present a highly profitable undertaking in competition with OPEC oil.

A further case in point is Sasol Three for which a minimum acceptable rate of return was calculated early in 1979 but as you can well imagine, the oil price increases of the last 18 months have already placed the prospective initial rate of return well above the minimum level postulated last year.

In this business it is the bold acting in a responsible manner who will earn the highest dividends.

Another vital aspect of alternative energy economics is the method of financing such projects. This is bound to differ vastly from country to country. In the case of South Africa, it was out of the question for two new Sasol plants with an end-of-job cost of \$7,5 billion including the associated coal mine, to be completed without direct financial participation by the State. But this has been very wisely arranged still to give the private investor maximum scope for participation in these ventures.

Last year two Sasol share issues were made: \$637 million to institutional investors and \$45 million to other investors and members of the public. The latter issue was 31 times oversubscribed, including tremendous interest from outside South Africa. Because of the excellent long term outlook of these energy projects, the Sasol shares have been called the most exciting energy stock of our time.

The private equity participation is initially based largely on the already profitable Sasol One operation, but there is provision for the closer integration of Sasol Two and Sasol Three into the group once these plants have gone into full commercial production.

In both projects 20% of the capital cost will be funded by way of loans mostly in the form of supplier credits. Then there is the contribution from the share issue of $682 million. The balance is being provided by the State, essentially in the form of equity participation.

Once these projects are in commercial production, the State will greatly reduce its participation by selling off shares in the group to private investors, allowing Sasol to retain the private sector character which it assumed last year.

An interesting feature of the financing scheme is the high ratio of equity type capital to loan capital. This is very desirable for this kind of project in the initial years of its establishment. In our case we intend to gear up to much higher than 20% loan capital, but only after each project is in commercial production. The advantages of this arrangement to the whole process of achieving early economic viability, are apparent.

The means adopted by the State for furnishing its stake in the capital of Sasol Two and Sasol Three is quite interesting. The Government can of course use any source of funding available to it. In this case, approximately 15% of the amount taken up by the Government will be furnished through normal appropriations by Parliament. The balance, which is by far the largest proportion, the Government is obtaining through a levy or tax on all liquid fuels sold, imported as well as indigenous.

There is no doubt that strategic considerations contributed to the spectacular progress which South Africa is making on the road towards energy independence. But as I have emphasised, all our actions to date can stand strict economic scrutiny and satisfy private investor criteria.

I need not dwell on the long term advantages that these projects will have in terms of foreign exchange savings which would otherwise be required for oil imports. Once these projects have come to fruition, one can speak only of benefits to the economy. The burning question is whether their establishment could be readily accommodated and digested in the economy without undue adverse effects on other sectors.

I can categorically say that in South Africa this was indeed possible. But again we had a number of factors that were working in our favour.

It is true that an oil-from-coal plant such as Sasol Two or Sasol Three does not provide, in relation to the size of the investment required, substantial additional employment opportunities. In fact, the average investment per employee in industry in general is about 1/30th of the investment per employee in the oil-from-coal industry. But then it should be borne in mind that it is not the primary purpose of the industry to provide employment for large numbers of workers, at any rate not in the long term.

During the construction phase, however, the establishment of a project such as Sasol Two or Sasol Three can have a major impact on employment opportunities, not only in terms of direct employment on the construction site, but also in terms of indirect employment in the manufacturing industry supplying equipment and materials to the project.

Construction manpower on Sasol Three will peak at about 27,000. Allowing for the indirect employment opportunities which are being generated elsewhere in the economy, 75,000 additional jobs will have been created by Sasol Three by 1981, for the duration of the construction period. This represents a contribution of nearly 1% of the total number of job opportunities in the economy as a whole at that stage.

In South Africa we are at present experiencing an upswing in economic activity. At first glance, it would seem that the timing of Sasol Three in terms of its overall economic impact, could have some unfavourable repercussions. In fact, however, this is not the case.

South Africa is passing through a transitionary phase in which the creation of employment opportunities for the large number of people entering the labour market each year is vital to the future economic and political well-being of the country. Most of these people are untrained and unskilled. The direct and indirect effects of the Sasol projects in the years between 1975 and 1983 in providing not only additional job opportunities, but especially in the training of unskilled labour into skilled and semi-skilled workers, will be of immeasurable benefit to the country. The total number of manhours generated by Sasol Three alone, both on the construction site and in the manufacturing industry, will exceed 250 million. In the process we will have trained nearly ten thousand previously unskilled labourers into fully skilled workers and many thousands more into semi-skilled workers. These people will be absorbed into the economy when construction has been completed.

If one further bears in mind that the capital expenditure on Sasol Three will represent approximately 4¼% of the projected total gross domestic fixed investment in South Africa during the period 1980 to 1984, the important position which this project has assumed in the present economic upswing becomes apparent.

So much for Sasol Three. What then was the effect of Sasol Two? In this case we were even more fortunate. Sasol Two came at a time when we were experiencing a general slump in the economy. The creation of job opportunities by Sasol Two was thus of even greater importance than is the case with Sasol Three. Taking into account the fact that more than 60% of the cost of these projects will have been spent inside South Africa, there is no doubt that the advent of Sasol Two was a major factor contributing towards the upswing in the economy that South Africa is now experiencing. Sasol Two took up practically all of the workshop capacity for fabrication of equipment for the process industries which otherwise would have been faced with very thin order books. Many of these industries also expanded their manufacturing capacity during this stage and a number of new industries were established. The additional capacity so created is a great asset to the manufacturing industry now that the economy is entering a boom period

In taking a bird's-eye view on the major expansion which the South African oil-from-coal industry is now undergoing, our biggest problem, namely the availability of sufficient numbers of adequately trained manpower will also become the most important spin-off from the establishment of these projects. That is, we will have trained a very large number of otherwise unskilled people in a variety of employment skills which they can now use to the benefit of themselves and the advancement of the economy as a whole.

In concluding my address to you tonight, I would like to bring to all of you interested in the establishment of a synfuels industry in the United States a message of high rewards in return for brave, but well deliberated and constructive action. But time is your enemy and not your friend in this endeavour. May you in the interest of this great country of yours, but also for the well-being of the rest of the free world, have much, but especially early success with your synfuels programme.

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