The Sasol Coal Liquefaction Plants: Economic Implications and Impact on the South Africa's Ability to Withstand an Oil Cut-Off


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Official claims that all three Sasol plants now operating can produce 100,000 barrels per day are specious. Total liquefaction capacity is probably close to 70,000 barrels per day. It can be safely assumed that South Africa has a serious shortage of diesel fuel, therefore the product slate has to be weighted to the lighter end.

The Fisher-Tropsch-Synthol process used at the Sasol plants was an
antiquated first-generation technology even when it was selected. Its thermal efficiency is low and its capital intensity is too high. Its thermal efficiency could have been higher if by-product gas could be used, but the plants would have produced it in quantities beyond what the market could absorb. The two new plants cost $5.8 billion, yet produce only 5 to 10 per cent of all energy in an economy with the gross national product of about $80 billion. The ratio of fixed plant to capacity is at least $58,000 possibly as much as $83,000 per barrel of daily output. Fixed costs cover at least one third of the price of motor fuels produced. The capital intensity of the plants is inadvisably high. The new Sasol plants are unprofitable and produce fuels at higher costs that if imported crude oil were refined. Their only rationale is that they are a strategic response to the oil embargo threat. Once this situation is removed, they will burden the national economy as unprofitable white elephants. Low-paid mine labour is the basis of costing in the entire energy, liquefaction and carbochemical industries. When this basis is removed, all profitability structures built on it will collapse. Motor fuel production at the new plants creates an enormous overcapacity in the country's conventional refining plants, which are largely owned by foreign oil companies.

Between interest on unamortized capital plant, opportunity losses on non-exported coal, stockpiling and the Sasol produced fuels, as well as extra costs for clandestine spot purchases on international oil markets, the current annual operating loss in the national energy sector may amount to $2.7 billion. When a decision on a fourth plant is made in the next few years, integrated two-state liquefaction developed by the Lummus Co. is the most suitable candidate for process technology, but it has not as yet been tested in a real-life plant.

Current domestic refined product consumption is estimated at 280,000 barrels per day, but could range from 250,000 to 320,000 barrels per day. Strategic stockpiles could range anywhere from 6 to 15 months of supplies. At these levels of consumption and storage, and at liquefaction capacity levels from 55,000 to 75,000 barrels per day, South Africa could withstand an oil cut-off for anywhere between 220 and 652 days.

II. SOUTH AFRICA'S ENERGY SECTOR

The question of the effectiveness of an oil embargo as a means of ending apartheid has been discussed for many years. One of South Africa's most successful countermeasures has been the construction and operation of coal liquefaction plants which produce motor fuels from coal. This countermeasure must now be critically evaluated in order to ascertain its impact on the capacity of the minority Government to withstand an effective oil embargo. In addition, we will also evaluate these new coal liquefaction plants from a technical and economic point of view and try to place them in the wider context of the South Africa's long-range economic growth and development. In order to accomplish this in the limited framework of this report, we must assume a certain basic knowledge of economics as well as of energy technology on the part of the reader.
South Africa’s energy sector depends to about 78 per cent on coal; coal is also the second most important export product. For both purposes, but more for the latter, coal production has been greatly increased in recent years and exports now amount to about 35 million tons per year. South Africa consumes about 1,656 million joules of energy per year, about half that of the entire African continent. Fifty-three per cent of this is used in industry, 25 per cent in transportation, 10 per cent in consumer households, 8 per cent in mining and 4 per cent in agriculture. Industrial demand for energy is currently rising the fastest, transportation the slowest, but this is largely because petroleum products, and especially diesel, are increasingly hard to obtain in the required amounts. Most energy is distributed in the form of electricity, often generated at power-stations near the collieries themselves. In fact, about half of South Africa’s coal is consumed somewhere in the immediate proximity of the pithead. There is a national parastatal electricity company, Escom, and a national grid which basically throws electrical power from the northeastern region, where it is still largely produced, to the southwestern regions. If and when South Africa begins to rely more heavily on external hydroelectric generated power from Mozambique, these tendencies will only be reinforced. The country’s first nuclear power plant, located in the southwestern part of South Africa where there is little coal, is about to be commissioned. It has been the object of considerable controversy and also of sabotage. In fact, the entire energy system is subject to sabotage to an extent which is internationally rare. There have been some interesting attempts to utilize hydroelectric power, but its long-term potential remains insignificant. South Africa’s major sources of hydro-electric power are all outside its own borders. In consequence of all this, somewhere around 20 per cent of the national energy consumption - that which does not come from coal - comes from oil. Comparatively speaking, this high reliance on coal and low reliance on oil is almost unique. 1/

It is precisely in this small margin of 20 per cent petroleum consumption that the apartheid system’s Achilles’ heel lies. There are two reasons for this. The country itself contains no deposits of petroleum. Almost all countries which produce enough petroleum to be able to export it are, for ideological, historical or commercial reasons, opposed to apartheid. At present, however, the same is certainly not true of those countries which market and distribute oil, although the international oil industry is gradually restructuring so that the exporters are gaining ground at the expense of the marketers. And, while the oil embargo has thus far been unsuccessful in stopping the flow of oil to South Africa, it has by no means been ineffective; it has forced South Africa to restructure its entire energy basis radically and at a cost in capital which it has had to borrow externally. In doing so, it has been forced to forego normal capitalist profitability considerations and channel investment into capital plant equipment which has no economic justification whatsoever outside of the present political context in which it has become necessary. If and when the oil embargo is ever lifted, the South African national economy will still be saddled with the Sasol coal liquefaction plants, as well as debts connected with
them which, as we will see, cannot produce liquid fuels at anything near the cost at which they could be obtained from crude petroleum, if and when it is available. In this sense they represent one of the most atrocious examples of politically motivated and economically unsuitable overinvestment in developing countries in recent decades.

In recent years, South Africa has had a Department of Mineral and Energy Affairs with a minister at its head. The ministry, in turn, has an energy branch which is further subdivided into four divisions, for coal, nuclear energy, electricity and liquid fuels respectively. Governmental regulation and supervision of energy have only been rationalized and co-ordinated in recent years, and largely as a result of the oil embargo threat. South Africa also engages in scientific research on energy matters, but some of this is obviously hidden from the public view in obscure parts of the public and private sectors. Moreover, the total amount of research is probably vastly insufficient to solve the problems the country faces. The apartheid system has created artificially expensive technology, research and development. In addition, South Africa's technical elite has been emigrating from the country for over 30 years. General research is co-ordinated and financed by the Council for Scientific and Industrial Research. The Council has an energy programme which was only started as late as 1978, and it is impossible to see from its annual reports exactly how much is spent on each project.

In any case, the total amount is pitifully low. In 1982 research was being conducted on power-line transmission, wind energy, electricity consumption, liquid fuels, fluidized-bed combustion of cola, residential energy use, and the production of energy from woodgas. Most of these approaches would only offer marginal alleviation of the South Africa's energy problems; the production of liquid fuels is the only one which can materially reduce the threat of an energy crisis. The Council for Scientific and Industrial Research has now also incorporated and expanded a Fuel Research Institute led by one T.C. Erasmus. Its budget of R2.2 million per year is financed by a levy on coal. The Institute is said to have a staff of 280,000 most of whom are concerned with research on coal. There is also an Energy Research Institute at the University of Cape Town led by Dr. Ryszard Dutkiewicz who has publicly expounded the view that the country spends far too little on energy research. Sasol Ltd. itself has a research staff of 120, of who 52 are said to be graduates. But its budget is only R2 million per year. It is difficult to interpret these figures, but between the Fuel Research Institute and Sasol, 400 people are employed at an annual cost of only R4.2 million, which means that only R10,000 per year per person is being spent on research. This is clearly of negligible value. Furthermore, it appears that much research is being done on the question of mixing various liquid fuels, particularly on attempts to stretch petroleum-based fuels by the addition of methanol. This approach is probably not a very promising one in view of the magnitude of the problem. Further research may be spread out further afield. One example of it is the research on sunflower oil conducted at an agricultural engineering institute subordinate to the Ministry of Agriculture and Fisheries, discussed below.
Altogether, this research is pitiably inadequate and could in no way perform the miracles required to save the apartheid system.

Concerning oil more specifically, we are faced with the problem that after 1978 the South African Government prudently suppressed all official figures to hide its vulnerability from public view. According to Bailey and Rivers, in 1978, the gross volume of petroleum processed by South Africa was 420,000 barrels per day, of which part was exported again. This figure however made generous allowances, amounting to 70,000 barrels per day, for oil being diverted to strategic stockpiling. Attempts to project current domestic petroleum consumption are hampered by the fact that 1978 was the last year for which we possess reliable data. Bailey has estimated the South Africa's domestic petroleum consumption at between 264,000 barrels per day (supposing 4 per cent annual growth) and 330,000 barrels per day (supposing 4.4 per cent annual growth). Our own estimate, elsewhere in this report, is at 280,000 barrels per day. Roughly similar estimates have been arrived at on the basis of similar quantifications of the effectiveness of conservation measure-and of demand growth. Beyond that, however, our estimates differ in that Bailey proceeds from a higher figure for both stockpiling levels and Sasol production. If we go back to 1978 and Bailey and River's breakdown and exclude re-exportation, there was at that time a domestic consumption of 273,000 barrels per day, 240,000 barrels per day being consumed as products, the rest being consumed in the conversion process. Of this, 26,000 barrels per day were going to industry and commerce, 36,000 barrels per day to consumer households and agriculture, 5,000 barrels per day to mining, and no less than 173,000 barrels per day to the transportation sector.

The country has four major refineries: two in Durban, one in Sasolburg, and one in Cape Town. The total refinery capacity in 1978 was estimated at 445,900 barrels per day. In 1982, it was variously said to be 423,500 barrels per day, or 476,000 barrels per day. In 1983, another source quoted the figure of 465,000 barrels per day. Even the lower estimates make one fact patently clear. These refineries were not operating near capacity in 1978, and Sasol liquid fuel production since then has deprived them of another portion of the business for which they were built. In fact, if South Africa's official claims about the extent of its demand and its own liquid fuel production were true, it would mean that the country's refining capacity is only being utilized at around 50 per cent. Whatever the case, this situation has ramifications and implications for the long run because these refineries are owned by foreign oil companies. South Africa's energy crisis is thus a source of loss to these companies because it prevents anything near a reasonable throughput level in the refining sector. What is furthermore of significance is that the entire refining capacity that originally existed was weighted in the direction of lighter products. Most recently, the authorities have started to revamp the refinery at Sasolburg, and a logical suspicion is that their intention is to gradually upgrade all refineries to be able to handle a wider variety of crude oils for conversion to a wider variety of products. This is especially important if South Africa is to be able to refine crudes from new sources, such as Angola.
The main argument of those who support the oil embargo against the apartheid regime is that oil cannot be replaced by anything else in the transportation sector, to which we can add the further argument that even liquefaction of coal cannot cover the increasing gap in diesel fuels. The original refining capacity would produce a diesel-petrol ratio which was not exactly desirable. The replacement by Sasol production of some of the imported crudes exacerbates this situation. In 1975, for every unit of distillate fuel processed by the refineries they also produced 1.06 units of motor gasoline. However, Sasol 2 and Sasol 3 with their Synthol technology produce 21.3 times as much motor gasoline as diesel. Therefore, if Sasol covers one-fourth of all liquid product output, it would mean that for every unit of diesel fuel available, the combined refining-liquefaction plant provides 1.32 units of motor gasoline. This means that there is too much petrol and not enough diesel. Diesel is used in agriculture and the commercial sector, petrol largely in the private automobile sector. Demand in the latter is elastic and amenable to manipulation by pricing and availability, but demand in the former sector is not such. Therefore, conservation methods tend to conserve what there is enough of and do not affect the main problem, which is diesel. The authorities have unofficially admitted that they have the petrol situation under control, but are worried that they cannot in the long run produce enough diesel. South African experts are obsessed with the question of how to produce diesel substitutes from all kinds of esoteric sources. A similar interest also motivates foreign researchers working for companies which supply technology to South Africa. In addition to developing substitutes, there is also a considerable obsession with the possibility of blending additives into diesel to stretch it. Especially naphtha and methanol have been widely discussed. Naphtha can be obtained as a by-product from coal liquefaction, while methanol is already being produced from coal in South Africa. Commercially, the mixture of diesel and methanol is called "diesanol" in South Africa. Another possibility would be to design smaller diesel engines. In fact, South Africa so much fears being cut off from import of diesel engines that in 1978 it decided to found its own domestic company, called Atlantis Diesel Engines, or ADE, to produce them. This company has, however, turned out to be a disaster, recently ending up with an enormous unsold inventory. Marginally, a certain amount of alleviation can be obtained by moving back into petrol for smaller or lighter vehicles. This would be feasible in road transportation and haulage, but still costly; in agriculture it is difficult to see what could be done. Ninety-eight per cent of the fuel used in agriculture is diesel and, as South African agriculture is under-mechanized at present, it is certain that there will be a significant demand growth for diesel in the future. This is indeed the Achilles' heel of the South Africa's fuel consumption pattern.

Finally, a word should be said about the pricing of petroleum products. The price of all fuel is artificially low in South Africa for historical reasons. The same has also been true of petroleum products, but this is now coming to an abrupt end. For one thing, the minority Government in South
Africa has traditionally subsidized agriculture, and even now diesel fuel is sold to the agricultural sector at a subsidized price. Otherwise, there is an officially regulated pricing of petrol at the pump. It is based on something known as the "average landed price", which in reality is the average price ex refinery, and it makes up about half of the final price to the end-user. The rest comes in the form of tax levies, and other sources, in addition to a retail profit for the distributor. Of the many components, the most significant ones are the Equalization Fund, which is paying for SasOl 3, and the State oil Fund, which is paying for Sasol 2. The latter was originally known as the Strategic Oil Fund. In the spring of 1983, petrol cost 59.6 cents per litre on the Rand. Of this, the retail margin was 3.7 cents per litre, railage from the coast made up 5 cents per litre, the base or refinery cost was 27.34 cents per litre and the rest (23.54 cents per litre) went to the Government in one form or another. In the autumn of 1984, the relevant minister released figures showing the following breakdown: landed price of 34.66 cents per litre, railage from the coast 6.5 cents per litre, retail margin of 3.8 cents per litre and a total Government take of 16.84 cents per litre, giving a pump price of 61.8 cents per litre on the Rand. The price was slightly higher, the components basically the same. The petrol price rose considerably in the 1970s, having been as low as 19 cents per litre in 1971, and reaching a high of 64.6 cents per litre in the summer of 1982-1983. It was officially brought down by 1.6 cents per litre in February 1983, and by an additional 4 cents per litre in September 1983. The South African Government respondend to the crisis of 1979 without the actual rationing of petroleum products in the normal sense. It did, however, manipulate consumption downwards by seriously curtailing the opening hours of petrol stations, which are still now basically closed on weekends. It relied additionally on price manipulation. This eased up in 1983 because - or so it is assumed - storage facilities were then filled to the brim, the early periods of run-down having been compensated when the Government recovered from the shock of the Iranian oil cut-off of 1979 and learned to obtain oil clandestinely. As the Sasol plants came on stream, the storage facilities were filled up again and the crisis can be seen as ending finally in September 1983. One word should be said about the price of petrol. It evolved historically at a time when internal production by Sasol made up 1 per cent of the total market. It is still based on the assumption that crude oil is being imported and has never been adjusted now that Sasol 2 and Sasol 3 are producing for the market. This means that the official "landed price" is a fiction arrived at on the basis of imported and refined crude oil. The actual cost of Sasol-produced refined product is summarily estimated and the product is sold at that price to the distributors. The loss due to the discrepancy Sasol products are much more expensive than those produced from crude - is compensated somewhere else in the system at a hidden point, probably in the form of a pure government subsidy injected into Sasol.

C. APARTHEID AND THE ENERGI CRISIS

The conditions prevailing in the South African energy sector are peculiar to the country due to its peculiar social and historical traditions. Some peculiarities have purely geographic explanations: the country contains rich
deposits of coal, none of oil; there is a shortage in the supply of water, but a
relative abundance of uranium, etc. But the most significant peculiarities from our
point of view go far beyond this and derive from the economic and historical
development of the country and the relations between its different groups of
inhabitants. One peculiarity is that development of the mining industry and the
development of racism have conditioned each other to a large extent; we will go
into the further ramifications of this later, suffice it to say here that if this
peculiarity of racism should ever be removed, it would change the entire structure
of the mining industry. The second peculiar influence on the further development
of the energy sector comes from the oil embargo. Due to disgust and indignation
at South Africa's apartheid system, other countries, in this case oil exporting ones,
have adopted a policy of no relations with South Africa, making the country's
access to petroleum very tenuous. This embargo is of an historically rare type
because the countries engaging in it are not basically in conflict with South Africa
over any concrete political or economic clash of interests. Nevertheless, in a
figurative sense, the country is very much at war with the international
community and to obtain oil it has to operate in secret on international oil markets
and pay a premium to obtain oil. This has cynically become known as the "pariah
penalty", an expression occasionally even used in the South African business
press. International interference with its oil supply makes South Africa rely on
dubious sources of oil ruled by autocratic and retrograde régimes which could be
swept away by popular revolution at any time; its original main source of oil, Iran,
was eliminated in precisely this manner in 1979.
The oil embargo influences the country's options and profits.
Nevertheless, it is in the nature of this embargo that it is transient, because it is
due solely to apartheid. But as time goes by, structures and preferences develop
with the raison d'etre largely influenced, if not solely necessitated, by apartheid.
But if apartheid and the oil embargo are removed, the entire basis for these
structures will be removed simultaneously. However transient the causes, some of
these structures are capital-intensive and highly immobile. They would have to
remain after their original cause has been eliminated. It is one of our basic
arguments that the Sasol coal liquefaction plants are grossly uneconomic and
irrational outside of the present context of apartheid and the oil embargo. In a
post-apartheid South Africa they would soon turn out to be economic white
elephants of an appalling magnitude. There is a third way in which the present
transient situation affects the energy sector, though it is a minor one. Energy, like
transportation and several other infrastructural sectors, is vulnerable to sabotage
and protective measures and devices have become necessary on a scale which is
clearly economically burdensome. Here too, the South African Government must
pay the price of being at war with its own people. These countermeasures go far
beyond what normal security requires and are typical of a civil-war-like situation.
While we possess no actual statistics, there is little doubt that they are extremely
costly both in money and intangibles because they obstruct normal efficient
operation.
Because energy in South Africa means coal to an internationally high
degree, amounting to about 80 per cent of the total, an understanding of the energy sector would have to say something about the production of coal through mining. The mining system still predominating in South Africa is now practically unique in the world, though it was common in many colonial societies. It is based on unskilled, poorly-paid mine workers who have often been contracted for in bulk on a temporary basis and who normally live at some distance, occasionally at considerable distance, from the areas in which mining is conducted. They are thus migrant labourers in fact, they are the main contingent in the entire pattern of migratory labour which has been characteristic of the colonial economies of all southern African countries. Alongside of these poorly-paid black miners, there have been higher-paid white employees who are normally referred to as miners, though in reality they are stewards or supervisors. These tendencies have been compounded by complicated agreements setting up specific ratios between the number of poorly-paid black workers and the number of highly-paid white workers and, for a while, even stipulating the exact discrepancies in pay between the two groups. As a further irony, until recently the black mine workers were legally considered servants and not workers, while the white stewards-supervisors were classified as miners and had trade unions which over the years have been one of the main sources of pressure for the maintenance of this system.

This is all in clear contrast with the way in which mining is conducted in other countries. Practically everywhere else miners are an elite in the working classf they are highly skilled, highly paid, they are very proud of their occupation and their traditions, they live permanently in close proximity to the mines and have even tended to become hereditary occupational groups. They were organized into trade unions at a very early stage and hence have been prominent in the trade union and working class movements and parties in countries such as the United Kingdom, Australia, Belgium and Poland. In fact, in these countries even governmental leaders have often been men of mining background. Even in Zambia, where mining started with exactly the same colonial system that South Africa still has, miners after a generation or so began to develop into a stable working class61ite which has become prominent in the country's political life. In general, the modern mine is no place for unskilled illiterate migrant workers. In the industrialized countries mines are airconditioned and heavily automated, miners are equipped with walkie-talkies and run complicated machines, and they have little use for things such as the pick and the shovel, and hardly even touch the coal. Thanks to racism, South Africa remained outside of this general development, though its mines are now becoming heavily automated and technically sophisticated.

On the basis of the above, it now becomes clear that the cost of the coal in South Africa, which makes it competitive as an export and as a source of energy via liquefaction, is clearly related to apartheid, racism and the South African mining industry's peculiar traditions of labour relations. There is a reciprocal and very tragic relationship between racism and this system. Racism originally grew up in a society which was agricultural and it was in the agricultural sector that the
system had its original rationale. It might just have died a natural death with industrialization, but in South Africa this latter started with mining, and at very early stages in the development of the mining industry racism could be fitted very well into its new context. South African racism, as it later crystallized into the apartheid system, was

the mainstay of a society which lived off agriculture of a marginally commercial type as well as off a mining industry which operated with low-paid labour and exported the country’s raw materials to the industrialized nations at an artificially low price. All further economic development in South Africa has come into collision with the racist labour relations originally evolved in the agriculture and mining sectors. As other sectors developed, more and more aspects of racism had to be dispensed with; or, occasionally, the predominance of racist patterns forced the economic growth back into mining. South Africa’s recent decision to become a major exporter of coal and to promote the precipitate development of the specialized minerials’ mining sector has therefore represented a tragic step backwards: back to cheap-labour mining, rapid depletion, under-priced exports and a position as a subservient supplier of raw materials to the industrialized countries.

It is only the low-cost labour in the collieries which, together with other economic structures of a largely racist nature, make it possible to cover the economy’s energy needs with coal to an extent of as much as 80 per cent. Normally, coal is converted into electricity which is transported and utilized in the industrial sector. Mines can easily use energy in the form of electricity. Later was developed a steel industry which could also make use of energy in this form. Meanwhile, agriculture was always under-mechanized and this stunted the growth of petroleum demand. This is how an 80 per cent coal/20 per cent oil split in the national energy-source slate became possible. As soon as the national economy tries to develop outside of the confines created by racism, it runs into structural obstacles from this peculiar energy-source slate. Let it finally be noted that the low cost of labour also influences coal consumption in the economy. Historically, coal first provided large amounts of energy in industrial complexes often via stream, on ships and in railway locomotives, by being fed to the firing point manually by a worker known as a "stoker". In the industrialized countries, as wage levels rose, the "stoker" had become an extinct species by the Second World War. One of the reasons why liquid fuels replaced coal was that they could be fed to the firing point mechanically and required less labour. Since then, mechanical means of feeding coal to furnaces have been developed, but they normally are only feasible in larger plants. In South Africa, where cheap black labour has always been plentiful, manual coal firing later became used extensively in electricity-generating plants and even many medium-sized buildings. The "stoker" still exists, though now he is being gradually replaced by machinery. Thus at both ends of the process - at pit-head and at furnace-mouth - coal only survived and became such a predominant source of energy in South Africa because of the existence of cheap black labour. Low-paid mine labour has also made coal viable as a chemical feestock beyond what is usual in the industrialized countries. In
South Africa, both methanol and acetylene are produced on a large commercial scale from coal. While the process technologies used would be feasible anywhere, they would be uneconomical at normal coal prices and hence are not used. 15/ A number of factors are now threatening the low-cost labour base of the South African mining industry. It had in any case been given artificial life by the apartheid system, but now forces are working against it more than before. In the opinion of many, the mining industry has simply expanded to the utmost possible extent on the basis of cheap labour; all further development, as profit margins press and more difficult seams have to be, worked, will require sophisticated equipment and methods, using fewer, but more skilled workers. Another foundation in the system is being threatened in that the docility of labour is coming to an end. Traditionally, it rested on migrant workers who had no long-term interest in their pay or working conditions and were not even employees in the terms of the law. They had no right to organize in any manner, shape or form. Trade unions are now legal for all black workers, including those in the mines. The National Mining Union, realizing where the Achilles' heel of the apartheid system lies, has openly set itself the task of organizing the migrant black workers as well as others. As a result, serious blows may be dealt to the system even before apartheid falls. Seen historically, moreover, low-priced labour also turns out to be a transient aspect of the industry. Yet the profitability of coal production and coal liquefaction is dependent upon it. Anything built on this foundation will have its entire profitability structure undermined if and when artificially cheap labour is no longer available. Coal liquefaction is capital-intensive and technology-intensive and requires only small amounts of highly skilled labour; but at its base - the coal mine - it is still labour-intensive. In addition to considerations of profitability, it is also vulnerable to politically motivated strikes. The Sasol plants seek to decrease South Africa's dependence on black labour in the collieries. It therefore simply trades off a threat to its stability in one area against a threat in another one, one where the threat may prove to be more crucial.

As we proceed from basics to details, we find that the system is replete with similar contradictions at every stage of the way. South Africa's further economic growth is dependent upon the expansion of the energy base. This is made more difficult because, not only are greater amounts of energy needed, but also oil must of necessity be even further reduced in the contribution it can make to the total national energy pool. Other countries have been able to decrease their dependence on oil by marginal substitution of coal for oil. At an 80 per cent level of coal-based energy, South Africa has no room left to manoeuvre in this direction. For this reason, and also due to the lack of access resulting from political considerations, South Africa's dependence on oil is greater than that of other countries. The system, based on cheap labour and poor technology is now trying to save itself from these consequences by switching to energy-production methods which are intensive in capital and technology. Thus the dependence is merely shifted in a different direction: less dependence on the Organization of Petroleum
Exporting Countries (OPEC), more dependence on Silicon Valley or the City. As far as political options go, this shift in dependence is preferable, but it is still a form of dependence. Another attempt to escape from the same consequences is to substitute with less economic forms of energy. Thus a system which expanded because of low-cost energy must now diversify for strategic reasons into more costly energy substitutes. The expansion of the total energy sector requires more capital in any case; Escom's foreign borrowing has become excessive in recent years. But by moving into things like coal liquefaction, the system is, economically speaking, trying to defend itself by eliminating one of its own main supports, i.e. cheap energy.

Faced with an oil embargo which it has brought upon itself, the white minority Government still has a few options left, but most of them are problematic in one respect or another. One approach is to explore for oil on its own national territory. We have dealt with this attempt in another report and it appears that there is no oil to be had if there be any, its volume is not significant enough to close the gap and the cost of producing it would be far above acceptable levels of commercial viability. Another possibility is to try to obtain oil from Angola. But this solution would be far from ideal because Angolan oil is normally of a lighter gravity, less suitable for South Africa's refining capacity, less suitable for diesel, which is where the critical shortage lies. In addition, Angolan oil is normally not marketed but used as so-called "supply oil" for the oil companies active in Angola, several of which are the national oil companies of Western or non-aligned countries. Attempts to get at larger amounts of this oil would bring South Africa into conflict with these companies. However remote the possibility of using this source, South African ambitions and fantasies in this direction have undoubtedly fuelled Pretoria's willingness to intervene in Angola in recent years, and has given it added reason for trying to eliminate the Southern African Development Co-ordination Conference (SADCC).

Another possibility lies in bio-mass and renewable substitute fuels. In particular, sunflower oil has been the object of much research as a substitute for diesel, particularly for use in agricultural equipment. The idea has been advanced to the effect that the agricultural sector could actually become self-sufficient in fuel if farmers set aside one-eight or one-tenth of their acreage for sunflower and then converted the oil to a usable fuel with the use of manually operated presses. It hardly needs to be added that this labour would actually be performed by the white farmer's black labour staff, hence fuel production would be shifted back into a sector more dependent on South Africa's internal enemies, again to escape dependence on its external ones. As a matter of fact, in 1982 South Africa announced that a significant breakthrough had been made in the use of sunflower oil as a diesel substitute. 16/ It was said at the time that details regarding the new technology would be announced at a scientific conference on vegetable oils later that year. But at the conference in question, held in Fargo in the United States, papers read by South African scientists showed that their country was nowhere near practical use of sunflower oil in diesel engines. 1/ Another possibility would
be to substitute electricity for diesel in municipal mass transportation by using trolley buses. Most South African municipalities, asked about this by the Government, have rejected the idea on the grounds that it was much too costly. In addition, it was pointed out that electricity is peculiarly vulnerable to sabotage. In general, it can be said that all attempts at conservation and substitution collide by substituting something else for oil one requires more energy or incurs greater cost; in addition, substituting petrol for diesel requires more crude oil or synthetic crude. Fischer-Tropsch product slate coming out of the Sasol plants is heavily weighted in the direction of motor gasoline. In recent years, there has been a shift away from petrol to diesel in order to increase the total efficiency of all petroleum used. Because of its reliance on the Sasol plants, South Africa must go in the opposite direction.

There are a number of other possibilities, most of which revolve around mixing or blending, particularly if one of the components is methanol, which can easily be produced from coal. These are all methods of stretching oil-based fuels, but they do so by increasing the total spent on fuel. Further afield, everything possible from wood chips to maize cobs has been considered as a possible source stock for liquid vehicle fuel. In the long run, solar fuel might offer a few possibilities. And the South Africans have scored one minor victory by developing a type of portable windmill used to power pumps and other small pieces of machinery in the agricultural sector. But this does not suffice to change the general picture. Whatever responses the system may evolve to cope with the situation, the lack of direct normal access to petroleum will in one way or another inhibit or distort South Africa's economic development. Self-sufficiency is costly in capital, thereby reducing the amount of capital the country can spend on capital equipment for other sectors. What is less obvious is that it is also costly in resources which could be exported and converted into capital at a more favourable rate. The minority Government likes to draw attention to the fact that coal liquefaction supposedly saves to the country large amounts of foreign currency because less oil is imported. This is a typical example of the superficiality with which the régime tries to reassure the doubting Thomases in its own midst. The Sasol plants operate on coal from captive collieries, transferred at cost; this is normally about one-third of the export value of the coal. The opportunity loss from this wipes out about 60 per cent of the savings in foreign currency. Other diseconomies in coal liquefaction wipe out part of the rest. Whatever difficulties may arise in the areas of industrial energy and space heating from South Africa's crimped access to oil, it is in the transportation sector that this problem poses the greatest threat, not only to development, but even to the maintenance of current standards. The family car and its use for joy-riding, picnics, camping trips, etc. is an elementary and inseparable part of the good life as it is lived by the white minority) severe prolonged shortages inhibiting or preventing vehicle use for these purposes would whittle away at the privileged comfortable lifestyle which the white minority is trying to defend. It would have worse effects in rural areas where the car is an important mechanism in
maintaining the social cohesion of the white minority; these areas are sparsely populated with whites, more densely populated by blacks, and the whites are dispersed on isolated farms; the village, the church and the stores are often at a distance which cannot be covered by any other means of transportation. The general view of most observers is that the form of rationing used since 1979 has not materially affected the lifestyle as yet. But the crunch is yet to come. There is another problem looming on the horizon. In 1979, there were less than a half million black car owners; by 1987 their numbers may total 1.5 million. 20/ The policy of the present Government necessitates the development of a certain middle class among the black population, and no middle class lifestyle is possible without increased car ownership. If this tendency should develop momentum in the coming years, then increased personal car ownership alone would cause serious increases in petrol demand. Thus far, it has not been so much the total demand which has been problematical, rather the skewed disproportion between rising diesel demand and increased petrol production. This inhibits the development of heavy vehicle transportation. It may cause South Africa to rely on smaller and lighter petrol-driven haulage vehicles. This again would lead to diseconomies because it would increase the number of vehicles, engines, tyres, etc., and even wear on road surfaces would probably increase.

As the entire apartheid system moves towards its terminal stage, complications of this sort appear everywhere in the economy, not just in the energy sector. Twenty years ago the minority Government tried to decrease dependence on black labour by encouraging white women to enter the labour market. It also tried to offset the decreasing white birth-rate by encouraging white women to become mothers and housewives. Nowadays, the advantages of the comfortable life which membership in the privileged minority brings, as well as the enhanced professional career opportunities which lighter skin colour entails, are being seriously mitigated for the white men by long periods of military duty which, to boot, removes males from the labour market in the critical years of their careers and creates a vacuum which blacks can enter. Defending privileges means more obligations. Wherever we look in South Africa, the same contradictions are operating as the system undermines its own foundations while trying to stave off its decline. Only in recent years there has been a difference in that the governmental leadership, the clique of middle class technocrats around the prime minister P.W. Botha, placed a much greater reliance on purely technical solutions to the white minority's increasing problems. Thus cumbersome and dubiously efficient arrangements like Sasol's coal liquefaction plants or the tricameral parliament are sponsored because they seem to promise greater alleviation than purely repressive measures. They also have the added advantage of mitigating South Africa's bad image among the bankers and businessmen of the OECD countries, on whose indulgent goodwill the minority Government must depend. But most of these purely technical arrangements do not reverse the basic trends operating over long periods of time; they normally have dysfunctional side effects. As we will see, coal liquefaction prejudices the country's future development by
forcing investment into a sector which has no rationale once apartheid is superseded.

D. COAL LIQUEFACTION AND THE NEW SASOL PLANTS
Coal liquefaction refers to the process whereby coal, which is a solid hydrocarbon, is converted to liquid hydrocarbons of any kind, but has come more narrowly to refer to the conversion of coal to liquid motor fuels. Historically, there have been two major methods of liquefying coal. The first method is referred to as hydrogenation in this report, but it is also known as direct liquefaction, degradation, or Bergius-process. With this method coal is subjected to extremes of heat and pressure and the coal molecule is thus softened up and hydrogen atoms are added. These recombine to form a resulting liquid which is higher in hydrogen content than the original coal and lower in weight. The first successful hydrogenation of coal was performed by Marcelin Berthelot, a French scientist who for a while was foreign minister of his country. But the process was perfected by Friedrich Bergius, a German chemist who worked for the BASF concern. The other method is here referred to as synthesis, also called indirect liquefaction, or Fischer-Tropsch process. In this method the coal molecule is subjected to such extremes of heat and pressure that it breaks apart into its component hydrogen and carbon atoms, more specifically into a gas known as synthesis gas, sometimes abbreviated as SNG which is a mixture of carbon monoxide and loose hydrogen atoms. This gas is then fed to a reactor where it comes into contact with a catalyst that causes the hydrogen and carbon atoms to recombine, resulting in a variety of new hydrocarbon products, some of which are motor fuels.

The type of synthesis with which we are concerned is more specifically known as Fischer-Tropsch. It was developed around 1925 in Germany by two professors of hydrocarbon chemistry, Franz Fischer and Hans Tropsch. Different variants of it existed, and the older ones developed in Germany were used largely to produce diesels. Besides experimental work performed in Japan and in the United Kingdom (by ICI Ltd.), Fischer-Tropsch technology was originally developed by its inventors and by Ruhrchemie AG at a liquefaction plant in Oberhausen near Essen. A number of other plants operated in Germany during the Second World War, all of which were extremely small and inefficient by today's standards. Coal liquefaction was first used on a considerable scale in Germany during the Second World War, when 4 million tons per year of motor fuels were produced by the Bergius process, and additional 700,000 tons per year were produced in Fischer-Tropsch plants, the largest one of which was in Leuna near Leipzig. Most of these plants were destroyed in bombing raids during the last year of the war, though small amounts of synthetic coal-based motor fuels were produced in the German Democratic Republic and Sweden into the early 1960s. After the Second World War large amounts of relatively cheap Middle East oil became available and the automotive fuel industry shifted to technologies used to crack heavy crude oil down to motor gasoline. This destroyed the economic basis for coal liquefaction for the time being. After the oil crisis of
1973, there was increased interest in cola liquefaction for obvious reasons, but in the meantime a host of proposals for new technology which had supplanted the earlier methods, had come along in the OECD countries. Almost all of these technologies were based on hydrogenation. We will go into the matter in more detail further on, suffice it to name here a few of the modern hydrogenation technologies which compete with Fischer-Tropsch: Exxon Donor Solvent (EDS), Mobil Methanol-to-Gasoline (MTG), H-Caol, Solvent Refined Coal (SRCl) and Solvent Refined Coal 2 (SYC2) and, more recently, Integrated Two-Stage Liquefaction (ITSL). Which of these technologies is better, is still a matter of dispute, but normally a technology is more or less suitable for a particular situation depending on which products are desired, what kind of coal is used for charge, how cheap or expensive energy is, etc.

"Sasol" is an acronym for the company's Afrikaans name which was "Suid-Afrikaanse Steenkool - Olie - en Gaskorporasie". Its official name is now Sasol Ltd. It first started as a vague idea for a coal liquefaction plant just after the end of the Second World War. It was incorporated as a state-owned entity by the new Nationalist Government in 1950. It began building its plant in 1953 and produced its first fuels in 1955. A town grew up around the original plant called Sasolburg, which is in the Orange Free State on the border of the Transvaal. The company was reorganized several times, its present form as a publicly-traded corporation dated from 1979. Seventy per cent of its shares are held by the public and 30 per cent are owned by the South African Government, more specifically by the Industrial Development Corporation and another parastatal company called Konoil. Despite this recent change in its technical ownership it still very much preserves its character as a utility closely regulated and run by the Government, for government purposes, including strategic ones. It divulges much less information to its own shareholders than does a normal public corporation in the Western countries and its exact management accounting can only be surmised by the outsider. South African passion for segregation and differentiation, so pronounced in the field of race relations, has not been extended into the realm of accounting, and Sasol's annual reports are an excellent example of what an earlier generation of racists used to call "mixed farming". They also contain striking omissions: for example, we now know ex post facto something about the amount which Soekor, a subsidiary of Sasol spent on exploration in past years; but this capital flow was not contained in the published annual reports of previous years. It is generally assumed that Sasol is receiving large capital injections from the South African Government, but of an unclear magnitude, and it is impossible to discern at which point, or points, this is being done.

Sasol's formal corporate structure is now something like the following: The group's holding company is called Sasol Ltd. This in turn is a 100 per cent owner of another company, Sasol One (Pty) Ltd. This company in turn has several wholly owned subsidiaries: Sasolchem (Pty) Ltd, Sasol Fuels Marketing (Pty) Ltd. (SFMC) and Sasol Technology (Pty) Ltd. (Sastech). It also
has a 52.5 per cent share in the National Petroleum Refinery of South Africa (Pty) Ltd. This latter is usually referred to as Natref. It owns a large refinery in Sasolburg, the rest of which is owned by the French Total Group and several large institutional investors. The National Iranian Oil Company was originally part owner of the Natref refinery. In addition to these subsidiaries, Sasol One (Pty) Ltd. has a 50 per cent share in the South African Gas Distribution Corporation (Gascor) which sells original plant which we refer to as Sasol 1. Sasol Ltd. has two other subsidiaries in which it has heretofore held a 50 per cent share: Sasol Two (Pty) Ltd. and Sasol Three (Pty) Ltd. Each of these companies runs one of the two new plants which we call Sasol 2 and Sasol 3. The remaining stake in them has up to now been held by the Government, again through the same parastatal corporations. At present, however, Sasol 2 is in the process of being privatized, which means that the Government is selling its half to Sasol Ltd, but largely by loaning the money needed for the purchase. The same thing will eventually happen with Sasol 3, but this is expected to take another two years.

Previously, Sasol Ltd. had another subsidiary called Soekor (Southern Oil Exploration Corporation) but it relinquished its hold over this in 1983 for reasons and under conditions which were never explained. There is an additional subsidiary in the group, Sasol Fertilizers (Pty) Ltd, which was originally a wholly-owned subsidiary of Sasol Three (Pty), but which was transferred to Sasol One (Pty) Ltd. in 1983, again for reasons not disclosed. The group further owns township and development corporation which own housing complexes for employees and other buildings in Sasolburg and Secunda. Through Sasol One (Pty) Ltd. it owns a number of captive collieries, such as Sigma which supplies Sasol 1, and a number of others near Secunda which supply Sasol 2 and Sasol 3. The largest of them is called Bosjesspruit. The corporate office of Sasol Ltd. is in Johannesburg, its Chief Executive Officer since 1976 has been Dr. D.P. de Villiers and its managing director is J.A. Stegmann. Another leading executive of the company for many years was one Jan Hoogendoorn, an engineer by profession who had been with Sasol 1 from an early stage. He tended largely to represent Sasol in the international coal and energy industry and was the author of technical articles from which outsiders' more precise knowledge of Sasol technology has been derived. Sasol's founder was one Dr. P.E. (or Etienne) Rousseau, who was the chief executive officer until 1976. In contrast to many other parts of the South African business community, Sasol has always been heavily Afrikaans in its executive leadership. Sasol 1, the original plant, came on stream in 1955. It had a two-track system in the second or synthesis state of the process. One of these tracks used a technology known as Arbeitsgemeinschaft Lurgi-Ruhchemie (ARGE), a more archaic one developed by Lurgi GmbH after the Second World War. The other track utilized the technology called Synthol, developed by the M.W. Kellog Company Inc. At present, the headquarters of this company are in Texas, United States. Since 1980, M.W. Kellog Company Inc. has been a wholly-owned subsidiary of Wheelabrator-Frye Inc. Since the amount run through the two
tracks could be varied, the yield could be changed. Synthol yield can also be manipulated by varying the amount of methane reformed as charge. The most important difference was that the ARGE-track (or fixed-bed track) produced 33.4 per cent of motor gasoline and 16.6 per cent of middle distillates, giving a better balance, but a lower total yield of motor fuels. Worst of all, it also produced 40 per cent of waxes. The Synthol-track produced a greater amount of motor fuels, but mostly motor gasoline. It also produced methane gas which could be, and generally was sold to outside users. But the methane could also be reformed back to synthesis gas to increase the motor gasoline yield, as we will explain later. Thus the yield of this original plant was highly variable, something which makes it hard to estimate what its actual capacity was.

Both these technologies were definitely superior to those used in the Second World War. They profited from years of precise research on detailed questions, mostly dealing with the optimal type of catalyst and optimal way of reacting it with the charge. Nevertheless, they are still considered first-generation technologies, and the other coal liquefaction technologies discussed in the 1970s are considered to be the second-generation. There is also a third generation of technologies, based on pyrolysis of coal, but these are as yet merely theories. Synthol was really the only technology available, since nowhere else in the world were there commercial-sized coal liquefaction plants. Yet much about it, especially details about the catalysts is actually a trade secret because Sasol always hoped to sell this technology and it was therefore sensitive about details which could shed too much light on questions of cost and profitability.

The minority Government first began talking seriously about major coal liquefaction production after 1967 and particularly in the early 1970s as oil embargoes came to be discussed more openly. They chose the Synthol technology for the most obvious reason that it provided more motor fuels than did ARGE. In addition, no other technologies were available at the time, and research on drastically new techniques was simply beyond the country's scientific and financial resources. They were aware very early of one significant problem. The original plant, being small in its total output could sell its methane by-product to industrial users. The new plants, which had to be much larger, would produce methane in quantities for which there was no market. Their methane could be reformed and fed back into the process, but in doing so there is a second large reduction in thermal content. This reduces the profitability of the entire process considerably. What is true of methane is true to a certain extent of other by-products. This is why, despite innovations, the profitability of the new plants is lower than that of the original one.

During the 1970s, the whole idea took greater shape. First, relevant technologies were chosen, and so was the site in Secunda in the Transvaal. By 1975-1976, contracts had already been signed with the major equipment and technology suppliers. But the entire project dragged on slowly for lack of financing or perhaps willpower until 1979, when the revolutionary Iranian Government cut off oil deliveries to the racists. Thereafter, the construction of Sasol 2 was speeded up and a decision made to construct another plant, Sasol 3, which was more or less an exact duplicate of Sasol 2. Contracts were simply
extended or doubled and outside contractors for Sasol 2 worked on Sasol 3 as well. Sasol 2 began producing in 1980, and it was fully on stream by 1982. Sasol 3 came up to full capacity production in June of

-1983. The period of time necessary for building the plants was record-breaking. Under the circumstances, the South African authorities were quite satisfied with the results, though construction had been marred by several incidents. One included attempted sabotage, not only against the two plants under construction, but even against the California head office of the major contractor. Simultaneous sabotage against Sasol 1 was successful and did cause costly damage. This incident exacerbated labour relations on the construction site and led to strikes in the winter of 1980 as well as to two days of arson and stone-throwing. According to Lurgi GmbH, each of the plants requires 3.5 million tons per year of coal to produce steam and electricity, and an additional 9 million tons per year of coal for charge, as well as 14,000 tons per day of oxygen and 100,000 cubic metres of fresh water. The site itself is 2.5 by 3.5 kilometres contains 156 buildings, 120 kilometres of underground piping and 5,500 kilometres of wiring and cable. At the peak of construction, there were 25,000 construction workers on site, and the two plants together required 190,000 tons of components. At times, heavy imported components weighing up to 400 tons had to be off-loaded at the port of Richards Bay and brought overland to the site with special vehicles. Sasol Ltd. estimated that 6 million man-hours per year were being spent on construction and that this would increase by another 50 per cent at peak. More telling is a figure which Lurgi has disclosed: 700,000 technical man-hours were used for designing and engineering work alone on its own part of the project. The number of technical staff which Lurgi put into the project went up to 160. This shows to what extent these plants are technology-intensive. This is one of the reasons why they are so expensive. They would have been even more expensive, however, if it were not for the fact that artificially cheap black labour from South Africa was used extensively in the actual construction process. We are not in a position to quantify this advantage, but it should not be overestimated. The bulk of the money for the plants had to be spent abroad, and cheap black labour - traditionally believed to be such a tremendous incentive to industrial development - could only mitigate this slightly. A somewhat simplified flow-chart is provided below to help in conceptualizing how the plant works. An equally simplified verbal explanation would be something like the following: Some coal is fired to provide power, heat and steam, while the bulk of the coal is ground up and moistened as charge. Elsewhere, oxygen is produced through air-separation. The coal, steam and oxygen are all together fed into the top of 36 enormous Lurgi gasifiers. Gasification occurs here as this mixture sinks towards the bottom. From different levels of the gasifier, ash, ammonia, phenols and tar emerge. They are then taken to separate filtering and refining units to be cleaned and upgraded to usable by-products. The main product from the gasifier is synthesis gas, which is a mixture of carbon monoxide and loose hydrogen atoms, but it also contains many
impurities and methane when it emerges from the gasifier. It is next put through something known as a Rectisol unit, where sulphur is removed. The remainder contains some methane. This methane may be reacted in another unit with more steam and oxygen and converted to the same kind of synthesis gas. Alternatively, methane can be used as fuel to provide heat. All available synthesis gas is then sent to a battery of seven reactor loops where it is brought into contact

-18-,  
SIMPLIFIED SASOL 2/3 PROCESS FLOWSHEET  
LiP, gasoline  
diesel, fuel oil jet fuel, chemical  

-19-  
with a variety of iron-based catalysts. Reaction takes place and a mixture is formed which is then sent on to an oil work-up unit which operates very much like a normal refinery. This distills out the liquid fuels, motor gasoline, distillate and jet fuel. The residue is then sent to a chemical work-up unit where similar refining and separation of alcohols and ketones takes place. Meanwhile, small amounts of tar produced at the beginning can also be put through an upgrading unit and converted to motor gasoline or diesel. The ethane or ethylene produced in an earlier stage can likewise be reformed back into synthesis gas and put into the reactors, or they can be separated, purified and used elsewhere as by-products.

The first stage of the process, gasification, is extremely simple but is also extremely costly because it requires large amounts of heat. It is also in this first stage that the greatest loss of hydrocarbon thermal content takes place. This will be important later on when we discuss the costs and profitability of this technology. The second stage, synthesis or reaction, is much more complex although much less expensive since it is highly exothermic, i.e. it produces its own heat. In order to understand later discussions of cost and profitability, it should be pointed out that this plant, like any other, has a certain total capacity. Plants rarely run at full capacity, most run at something known as operating capacity which amounts generally to about 90 to 95 per cent of full capacity. All cost projections are basically done on the assumption that the plant is running at operational capacity. At least on an analogy with what we know of refineries, we can assume that the actual cost of the products becomes much higher as the throughput sinks. For one thing, the cost is dependent upon fixed costs which are incurred even if no production takes place. In the case of the Sasol plants, these make up at least one third of total, although even the operating costs are maximally geared to operational capacity. If, for one reason or another, throughput must be reduced significantly, cost rises rapidly; there is normally a minimum amount which can be run through the plant for safety reasons. Thus the Sasol plants must also have large buffer storage units around them to store coal, motor fuels and by-products. This is because any abrupt disruption in either supply or off-take would otherwise necessitate costly reductions in operational throughput. It is therefore logical to assume that some of South Africa's strategic
petroleum storage is probably located in the immediate vicinity of the Secunda plants and connected to them by a pipeline system. The official statistics are that Sasol 2 cost R 2,503 million and Sasol 3 R 3,276 million. The total would be R 5,779 million, which is the price of the plants themselves excluding township development costs (housing), interest during construction, and working capital. In the year in which these accounts were closed the rand had sunk, but foreign obligations had been assumed at a time when the currency was in a better position. The dollar figure normally given is $5.8 billion or $5.9 billion, total cost for both plants together. Taking the lower variant and the South African claim that the plants produce 100,000 barrels per day, this works out to a coefficient of $58,000 per barrel of daily production capacity. If the capacity amounts to 70,000 barrels per day, the figure becomes $83,000 worth of capital plant per daily barrel of production. This shows to what extent these plants are incredibly capital-intensive. One-third of the cost of the output lies in the fixed capital costs. In a country with a Gross National Product of about $80 billion, $5.8 billion must be tied up in plants which probably only produce 5 to 10 per cent of the national energy supply. An investment of this capital intensity could only be justified if it could be expected, beyond any risk, to bring a massive return on investment) yet it was accepted a priori that it would not run on a profit. This alone suggests that Sasol's fuels must be priced significantly above the price of those refined from crude. 25/

Net current assets of Sasol Ltd. at the end of fiscal 1983 were R1.27 billion, its actual equity only R998.4 million. The discrepancy is paid for or owned by the South African Government. The exact mode of financing has never been clarified, though claims have been made that, for example, with Sasol 3, 20 per cent or R655 million were financed in foreign credits. It is safe to assume that the vast bulk of these costs were financed by South African governmental borrowing. Sasol's accounts, as they appear in its annual report, hide the exact location of assets and the direction of transfers within the group. Its annual report for 1983 claims that Sasol 2 contributed R15 million and Sasol 3 R 10 million in dividends to the parent company. Where these originated, and what gross lies behind them, is not indicated. It is everyone's assumption that a loss is being financed by the South African Government, but where this loss occurs in the books is not clear because it can be moved around in the group or even spread out. But a hint of what goes on is obvious in the annual report for 1982 when the chairman, Dr. de Villiers, states: "A further essential prerequisite for a favourable investment climate in syfuels is the continued assurance that the prices of locally produced synfuels will in the long term remain linked to international fuel prices". 26/ This together with public remonstrances about protecting domestic synfuels hints at what we suspect. What the Sasol chairman means is that Sasol-produced fuels, which are inordinately expensive, should be given a protected slice of the market and not exposed to competition from imported crude-based products. Some kind of a gentleman's agreement must exist between Sasol and the Government that the loss incurred because of Sasol products' higher price be compensated by the
Government. But, like any gentleman's agreement, businessmen are leary of it because a financially strapped government might try to back out of it from time to time. One possible way of doing this is to rely on imported fuels as much as possible, because they are much cheaper and to buy less from Sasol, perhaps doing so more when the external spot market is favourable and then going back to Sasol products when it is not. This can force Sasol to reduce its throughput through the plants, something which, as we have explained, incurs further losses, losses which are probably not covered by the gentleman's agreement. It appears that everyone is doing his patriotic best to defend apartheid; but there is some minor squabbling about who should bear what part of the cost.

Finally, it should be mentioned that Sasol 2, officially valued at R2.62 billion, is being largely privatized as the Government sells its half. Since the Government also owns a share in Sasol Ltd., the cost of the privatizations is lower, and much of the money needed to buy out the Government's share is being lent to Sasol by the seller on a 5-year amortization plan. The issue, opened to subscription in early December 1983, old very slowly, one reason being the fear of investors that it will not return good earnings in the coming years. But, in addition, it is an enormous amount of capital to be raised on a small stock exchange such as the one in Johannesburg. The public has been lured into a more receptive mood with talk of great profits to come, once Sasol's chemical ventures get going. L7/

Whatever segment of the motor fuel market Sasol production now covers, it can only decrease in the future as total demand increases. In fact, Sasol's managing director Stegmann has frequently gone on record with the statement that the country must build Sasol-sized plants once every five years in order to come up to 65 per cent domestic fuels coverage by the year 2000. 28/ Behind this is another of his frequently repeated assumptions, that black car ownership will increase drastically in the future and become the main source of demand increase. Thus the South African authorities will sooner or later have to decide on new plants. Who will operate the next one, when and where it will be built, and what kind of technology will be used, is all still unclear. There is a vague consensus on two things, one that a decision must be made around 1985, two that the same type of Fischer-Tropsch technology will not be used. Behind-the-scene wrangling and dissension seems to go on. In previous years, it occasionally seemed as if the major Afrikaans mining group Gencor was trying to muscle in on Sasol's domain. Now it appears that Sasol would actually prefer to have Gencor lose money on synthetic fuel production, and that the latter is holding out for a better deal before it takes the plunge.

Gencor very early and very categorically refused to have anything to do with Fischer-Tropsch technology; Sasol apparently feels that getting involved with a completely new technology will be beyond its capacities, or that it would be too unprofitable. In the annual report for 1983, Dr. de Villiers pointed out that improvements on existing plant and technology would have to take precedence over other considerations in the next few years and added: "Hopefully, the
Incentives envisaged by the Government will in the interim lead to at least one meaningful synfuels project being undertaken by another South African group.\footnote{29/}

This is another way of saying: "It's somebody else's turn next!"

Previously, there had been much discussion over the possibility of a fourth plant; there were conflicting reports about sites, technology and financing, and at one point there were rumours that an official announcement would come at any time. Sasol quashed all this in September 1982, when it became clear that they would build a fourth plant in the foreseeable future. Earlier discussions had centered around Gencor and (state-owned) Sentrachem Ltd., and sometimes around a subsidiary of the former called Genmin. At one time, Ashland Oil of the United States may have been interested in such project.\footnote{2/} Ashland did test certain of its own coals in the Sasol plant, and the public outcry of indignation which this caused in the United States may have scared them out of further plans for South Africa. It was also rumoured that the "Kentucky" coals tested did not do well. In any case, Ashland later shelved plans for coal liquefaction plants in the United States. On another occasion, there was a vague discussion about some hydrogenation method of interest to Gencor which was not clearly identified, but which could cope with the high-ash coal from the Springbok Flat coal fields in the Transvaal that Gencor wanted to use as a source for a possible liquefaction plant.\footnote{1/}

Whatever the case, nothing concrete developed.

It is patently clear that the South African authorities do not want another Sasol type Fischer-Tropsch plant. Their position confirms what we know otherwise: that the process is costly and unsuitable, and that they would not have chosen it in the 1970s if they had any options. Sasol has for many years been doing research on hydrogenation,\footnote{L/} in particular with Solvent Refined Coal (SRC) types of hydrogenation. Otherwise, their efforts have been directed at trying to make hydrogenation technology suitable for high-ash content coal. At one point they were developing a process for brown coal, which they are unable to use on South African coals, and discussions were going on with Japanese, United States and Australian companies. Beyond an agreement to build a demonstration plant, which never materialized, nothing came of all this. Since a decision must be made soon, the only feasible solution which now appears on the horizon is something which is known as Integrated Two-Stage Liquefaction (ITSL of TSL). We can be sure that discussions have been going on between the South Africans and the developers of this technology; but the South Africans have never mentioned it in public, perhaps out of prudence. They are probably discreetly waiting to see how advanced the process is and what it will cost.

Integrated Two Stage Liquefaction, developed out of the Solvent Refined Coal technology is, in fact, a form of it. In principle, it is a form of hydrogenation which separates liquefaction and upgrading into two stages. It is therefore similar to synthesis in certain respects, but it requires much less heat. Coal is first treated into a slurry past; it is then "hydroliquefied" when hydrogen is added, and it is converted into liquid form. This is then taken to a refining or upgrading stage which uses LC-Fining technology; finally the resulting product is de-ashed. It is,
however, more complicated than this because hydrogen is introduced at two stages of the process, and de-ashing is also possible at two different points. In fact, it is called "integrated" because residues from one stage can be looped back to a previous stage continuously to increase yields. It has been developed by the Lummus Company, particularly by its researcher Dr. Harvey Schindler, at their laboratory in New Brunswick in New Jersey, United States. Most of the process is the proprietary technology of C-E Lummus, its parent company. C-E stands for Combustion Engineering, one of the original components in the conglomerate. The LC-Fining process, however, is jointly patented with Cities Services Company. There has been further experimental collaboration with Socal, which is testing aspects of this process in its refinery at Richmond in California, and subsidies for its development were originally received from the United States Government via the Department of Energy. 2/

Reasons for preferring this technology are that it requires a relatively low temperature and a definitely low pressure level. It is also said to make more economic use of hydrogen and the slate is largely distillate with some naphtha. This is precisely what the South Africans could use. This would satisfy diesel demand; the naphtha could then be used as an additive to upgrade motor gasoline from Sasol. Because the conditions required, such as temperature and compression, are much less severe, it is assumed that it is much less costly. Although all public discussion of this process comes from the designers and patent-holders, they have not said a word about their price. The descriptions published also imply that the process could even

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handle very high-ash coals, since it was originally designed for "Illinois" coals. We can be certain that the South Africans have been in contact with this company over this technology. Practically nobody else is at present in the market for coal liquefaction, certainly no one else is interested in a distillate-weighted product slate. Probably Pretoria is having feasibility studies done and negotiating over possible prices. It is not at all certain just how advanced the process research is, and just when and how fast it could be scaled up for a commercially sized plant. It is also questionable if the South African authorities can risk taking on a technology which has never been tested in an experimental-sized plant. At any rate, by 1985 a decision must be made. If they decide on a plant using the Integrated Two-Stage Liquefaction technology and start immediately, it could be on stream by 1990, with good luck even by 1988. But even if this technology is more suitable and less costly, it still remains questionable if it is a meaningful step in the right direction in the national economy's long-range development. Its strategic relevance for the minority Government is obvious; its long-range relevance to the country is not.

E. THE ROLE OF FOREIGN COLLABORATORS

It would go beyond the scope of this paper to discuss in any exhaustive manner the relations between the white minority Government and the many external suppliers of equipment and technology who collaborated on this project. An industrial project of this size and complexity needs all kinds of technology and
equipment which South Africa cannot produce. Appearances and advertising claims notwithstanding, its entire society is much less receptive to technology and development. Tensions and uncertainty caused by its racial mores have been stimulating white graduate emigration for over thirty years. During approximately the same time period, an education system imposed on the black population was explicitly tailored to suppressing a rise in their educational level. It followed on a long series of other structural arrangements which had attempted to do the same thing in a less explicit manner. Although the white minority Government did not realize it at the same time, it is impossible to suppress the educational level of one segment of society, the majority to boot, without having this reverberate on other segments. It thus contributed to the country's low productivity and inefficiency in the industrial sector. Even without this, the country would have difficulty producing the necessary technology or expertise; it is, after all, a developing country.

The foreign suppliers and collaborators involved in the Sasol project have thereby increased their visibility on the South African business scene and can be expected to be found participating in more projects in the future. In general, they show a slight shift towards more American firms, an increase in certain firms from the Federal Republic of Germany, both at the expense of British collaborators and oil companies. The companies involved were all involved with Sasol 1 and similar types of work in previous decades when this sector of the South African economy was much smaller. The only real newcomer is the United States Fluor Corporation. Noticeably absent are the older British collaborators in the chemical and mine-related industries, as well as the major oil companies. The latter, indeed, must have an ambivalent attitude towards the whole thing, for they hope to benefit in the future from an

-expansion of the South African coal industry, while Sasol and other coal-based industries in the country damage their market for crude and refining. But they have always collaborated with Sasol Ltd. in refining and distribution, and they do own blocks of shares in Sasol.

The main contractor for Sasol 2 and Sasol 3, and certainly the largest single beneficiary, has been the Fluor Corporation of Irvine, California. It was awarded this contract in 1975 just as it was about to enter a period of considerable expansion. The Sasol contract must have been a major motor in this expansion, for in 1981 it provided the company with $632 million in revenues, amounting to 10 per cent of the total. Fluor Corporation is an excellent example of the up-and-coming type of Sunbelt enterprises behind the Reagan Administration. They have an established reputation for technology, very healthy growth rates and have previously had an excellent earnings history, though they have recently run into financial trouble due to an ambitious acquisition. The present Chief Executive Officer, Mr. J. Robert Fluor, is not the founder but the son of the founder. The Fluor family does not really control the enterprise any longer, but Mr. Fluor is nonetheless an almost classic example of the self-made man or first-generation Sunbelt capitalist of the type popularized by the television programme "Dallas".
He is a vociferous right-winger, quite hostile to trade unions and increasingly involved in conflict with them because his company has acquired collieries. His associates appear to be of the same frame of mind and they are often more interested in politics than in business. The corporate statutes actually contain a prohibition on the company subsidizing Marxist-Leninist university teachers; several years ago an unedifying row broke out at the annual meeting, when a group of shareholders, standing even further to the right than Mr. Fluor himself, began to accuse him of violating this corporate principle because of a training cooperation deal he had made with a Chinese university. One of the most regrettable aspects of the Fluor Corporation’s collaboration with Sasol is that Mr. Fluor himself has actively and publicly taken up the cudgels for the racist minority Government. Together with a handful of companies in mining and mining-related industries in the western part of the United States, they represent the only section of the Western business world which is unabashedly and vociferously pro-apartheid. Almost all other parts of the Western business community seek to profit from collaboration with South Africa while maintaining a discreet distance to the minority regime itself.

For all its public verbal support for the white minority Government, the Fluor Corporation is actually exploiting South Africa in several ways. This is partially seen in the way in which the company has formed South African subsidiaries, some of which are joint ventures, to handle this contract. When it comes to simple things such as construction, Fluor is more interested in sharing the stage with local capital, but it keeps relatively exclusive control over the engineering and the technology-intensive subsidiaries. By selling technology to the South African whites, the latter acquire it to a certain degree; but Fluor is interested in preserving the South Africans’ long-term need to buy more, so it tries to fork it out in modest amounts. The Fluor Corporation has become greatly involved in synfuels development, and particularly coal-based ones. Its problem, however, is that these specialties cannot really be developed in the United States at present because economic trends are still working against them.

When the price of oil failed to rise rapidly, and even fell back somewhat after 1980, the market actually turned against the Fluor Corporation and its specialty. This only increased Fluor’s interest in the Sasol contracts and similar ventures. The white minority Government was motivated by strategic considerations, could not afford to consider profitability, could not wait, and it was in a poor bargaining position vis-à-vis foreign technology suppliers. Hence it could supply the Fluor Corporation with a very large contract at a time when the market was moving in the opposite direction, thus involuntarily assuming responsibility for financing synthetic fuel research and development which Fluor would be able to cash in on when the synfuels market ripens in the industrialized countries. In this sense, South Africa, a developing country in Africa, is actually providing foreign development aid to the United States, while in the short run it is financing Fluor’s expansion. Nonetheless, Fluor at one point brazenly wanted the United States Government to provide export credits for the Sasol project but it was rebuffed by
the Carter Administration. Since then, even more synthetic fuel projects have been shelved; South Africa needs this technology at precisely the moment when other customers are falling by the wayside. The theory has sometimes been advanced that technological innovations can never really be introduced and developed on the basis of profitability alone: normally, extraordinary circumstances of some type or other are necessary to get a new technology off the ground on a non-profit basis. To the extent that Sasol is financing the development of coal liquefaction technology, this is certainly true.

Thus the Fluor Corporation has been feathering its nest off governmental subsidization of unprofitable plants on a grand scale, particularly in the case of the Sasol project. But this does not prevent the company from claiming the Sasol project as a victory for free enterprise and castigating the United States Government for failing to finance the company's expansion on similarly generous terms. One of Fluor's independent consultants, Mr. R.W. Johnson, has provided us with an increadible example of this hypocrisy in an article in which Sasol Ltd. is portrayed as a successful capitalist enterprise, while government-owned United States Synfuels Corporation, which has turned down both Fluor and Sasol technology out of profitability considerations, is castigated for ingratiuously having refused foreign aid from South Africa. It is thus obvious why Fluor and Sasol got involved in this marriage of convenience at precisely the point where it took place. There is the additional possibility that Pretoria chose Fluor because of the corporate leadership's political orientation. The South Africans have in recent years had bad experiences with certain publicly-traded corporations in the West, sometimes because they operate in areas where public opinion will speak out against their collaboration, sometimes because shareholders balk at it. No such problem with Fluor. Just on purely operational grounds, the minority Government has every reason to be satisfied with Fluor's handling of the contract: the plants were finished in record-breaking time and apparently within budget. Fluor can now look forward to many further South African contracts, indeed the first benefits have come in the form of contracts for maintenance of the new Sasol complex and for revamping the old refinery at Sasolburg.

The second major collaborator was Lurgi GmbH of the Federal Republic of Germany, a wholly-owned subsidiary of Metallgesellschaft AG. The parent company has other interests in South Africa, inter alia in mining fluorspar. Lurgi's participation is the logical result of the fact that it collaborated at a very early stage in designing the original Sasol plant shortly after the Second World War. It produced the gasifiers in the original plant and replaced them with upgraded models several times. It is certainly the most logical choice for much of the gasification equipment. They have also produced much of the equipment used in phenol recovery, in the Rectisol unit, and so forth. Here again the Sasol contracts were extremely important. The new Sasol plants alone house more than half of the large gasifiers which Lurgi has produced. Lurgi components in the Sasol plants are said to come to a total value of DM4 billion. Lurgi has also provided us with interesting details on the transnational and inter-company collaboration which
went on during the design and construction stages. Involved were the head offices of Fluor in California, of Sasol in Johannesburg, of Lurgi in Frankfurt, as well as of Fluor's and Lurgi's subsidiaries in South Africa, and even of Lurgi's Japanese subsidiary in Tokyo. Engineers from all these participants were assigned to each others’ offices; Lurgi alone had 160 technical employees working on the contract at one time, and has qualified its design and engineering effort to 700,000 "technical man-hours". 35/

Lurgi has an obvious long-range interest in coal conversion, but more in gasification than in liquefaction. However, their gasifiers can be used for several different things, hence they are less affected by they low profitability of Sasol's dead-end Synthol technology. They too have been rewarded with further contracts, inter alia to provide gasifiers for South African power-stations. 36/ One of the most interesting details which emerges from Lurgi's description of the collaboration work is that much of its work (engineering and production) was carried out by its Japanese subsidiary. Japanese companies of this type are noticeably absent in South Africa because Japanese law more or less prohibits collaboration. But the subsidiary in question, wholly owned by foreigners, did not fall under the same provisions. Transnational corporations are much less affected by purely national legislation.

Going further in descending order of size, we could mention Linde AG, a company from the Federal Republic of Germany chosen by Lurgi as its subcontractor and specializing in gas technology. It provided many tanks, vessels, heat exchangers and contributed to the construction of part of the plants and to the installation of the equipment. According to its 1981 report, African contracts generated 21 per cent of incoming revenue, but this included other projects in Zambia and Egypt. Thus we see, as we go further afield, that the significance of the Sasol contract to the foreign collaborator declines relatively. In a somewhat different situation is the French company L'Air Liquide. The Sasol contract was not all that significant to this company in terms of its global activities, but the oxygen plant which it built for Sasol is probably the largest in the world. Beyond its financial benefits, the Sasol contract gave to L'Air Liquide the opportunity to gain experience in a project of unique dimensions in their branch. The same company has now received other contracts, albeit smaller ones, from other South African companies. The United States Westinghouse Corporation is in a somewhat different position, its collaboration on a number of projects being of major significance to the South Africans. South Africa, however, is much less significant to the Westinghouse, given its own enormous size. Its main collaboration has been outside of Sasol, revolving around coal gasification, development of fluidized-bed combustion for use in power-plants, as well as in the area of nuclear power. Its main interest in Sasol was to build a demonstration plant within the complex, but profitability considerations later led Westinghouse to withdraw. It has also withdrawn from other South African projects; so its involvements in South Africa will probably be limited in the long run to nuclear energy.
In a project of this size, the major contractors have their sub-contractors, who, in turn, have their sub-suppliers and so forth. The further down the line one goes, the greater the number of participants, the smaller the contribution, and the less chance that this participation is a piece of general public knowledge. Thus AEG-Kanis of the Federal Republic of Germany received a contract to provide the new steam turbines for Sasol 1. The Process Management Division of Honeywell of the United States provided the control systems for the new Sasol plants. Badger, a subsidiary of Raytheon of the United States had been selected by Fluor in the 1970s to do the engineering scale-up for the two new plants; it later signed an agreement with Sasol with rights to do the same for any other Synthol plants built elsewhere. United States Steel has received a contract to design an ammonia recovery unit for Sasol 1. Occasionally, minor participation takes the form of a joint venture with the client. Thus Sasol Ltd. and Sdecchimie AG of Munich in the Federal Republic of Germany have formed a joint South African subsidiary, African Catalyst (Pty) Ltd, to produce the catalysts to be used in the liquefaction plants. They, in turn have a standing purchase agreement with the South African subsidiary of Hoechst AG. Thus the circle closes, for another Hoechst subsidiary is Uhde GmbH, which designs and builds heavy chemical plants, and has in the past done so for many of the ancillary industries in Sasolburg.

The smallest unit in all participation is that of the individual consultant, like the so-called "head-hunters", or recruiters of professional staff. Normally unincorporated individuals who shy away from publicity, their participation completely escapes any exact identification. South Africa originally lacked the engineering personnel needed to run the plants; it now appears that it had considerable difficulty in producing them and was obliged at a late date to recruit abroad. Thus we hear that "overseas recruiting alleviated somewhat the persistent shortage of certain categories of skilled personnel". Internationally, such engineers are normally recruited to the industrialized countries from the Third World, a solution which was impossible here for pigmental reasons. Since people with those qualifications in the OECD countries would have little interest in going to live in South Africa, we can assume that, even here, the white minority Government had to pay a "pariah penalty" to get what they needed. At all levels of collaboration, from the largest to the smallest participants, we cannot really say on what grounds collaborators have been chosen. We cannot even say if South Africa really chooses them, or if it, in turn, has been the chosen. The pattern over time changes with respect to the nationality of the companies, United States companies replacing British ones, but we also believe there is a trend towards smaller non-public corporations. One possible explanation is that such companies are more interested in South African business and will give better terms. But Pretoria may also be afraid of adverse publicity or hostility from shareholder groups in larger companies. On a few occasions in the past, these factors may have caused companies to back out of South African involvement.
There is also a reverse type of collaboration in which Sasol tries to sell its technology abroad, but it has so far been very unsuccessful. Fluor has exclusive marketing rights to Sasol technology in the United States, but it has really not sold it to any extent. Sasol was at one time working on a form of hydrogenation, said to be similar to Solvent Refined Coal technology (SRC), which was to be commercially developed by a Japanese-Australian consortium known as Kominic. The technology was said to be suitable for lignite; the project was eventually shelved. Sasol plants have also been used to test foreign coals for companies interested in developing gasification and liquefaction facilities of their own. Sasol has previously done this for Phillips Coal of Texas and Ashland Oil of Kentucky, as well as for the Great Plains Gasification Project in North Dakota, in which Lurgi is also involved. By 1983, all major projects of this type had been deferred. Sasol technology is not competitive where the client is interested in profit and has some options. The South African authorities were motivated by strategic concerns and had no options, and that is the only reason why they chose it in the first place. It is doubtful that Sasol technology will be developed or sold in the future either. The political objectives of the South Africans in developing coal liquefaction would not in themselves exclude the possibility that liquefaction plants could be useful to others. In the last years of the fascist dictatorship, Portugal built both the bridge over the Tagus and the hydroelectric dam over the Zambezi; both of them survived the regime that built them and serve its more progressive successors very well. The waning years of the Shah's régime were also characterized by a similar outburst of construction of high-technology plants. Historically, the best example of this is probably the highway system built by the fascists in the Third Reich, originally with military objectives in mind; they too survived their origins and became eminently useful to successor States for more peaceful pursuits. Is there therefore a chance that the Sasol coal liquefaction plants will someday be useful to a post-apartheid Government in South Africa? This seems highly doubtful to us. Perhaps if South Africa now builds a coal liquefaction plant based on the Integrated Two-State Liquefaction (ITSL) or some other improved technology, then this could be argued; it might also be argued with reference to coal-based methanol plants or the increasing use in South Africa of coal as a feedstock for chemicals and fertilizers. But this could hardly apply to the Sasol 2 and Sasol 3 plants because of the disastrously low thermal efficiency and profitability of their Synthol technology. They are, from a long-term point of view, white elephants and a future South African Government will probably regard them the same way the international energy industry now does; as an enormous misinvestment which served the transient interests of the minority at the expense of the long-term needs of the national economy.

F. ESTIMATES OF PLANT CAPACITY

The production of liquid motor fuels from coal at the Sasol plants is one way in which South Africa evades the oil embargo and reduces its effectiveness. If we can quantify the amount of coal-based fuels being produced, we can then better judge the extents to which the white minority Government has reduced its vulnerability to the embargo, and how many further
efforts, and of what kind, we must make to enforce it. Let us first review the
difficulties inherent in trying to estimate the capacity of the three plants. Our first
and foremost difficulty is, of course, the fact that South African law since 1978
puts a blanket prohibition on divulging anything which would permit such an
estimate outright. Thus statistical data of an economic or technical nature are
suppressed, garbled, and - most probably - even falsified by the South African
authorities themselves in order to prevent such estimates. But the problem goes
beyond that, because the exact yield of the original Sasol plant has been a
controversial commercial secret ever since it started in 1955, long before there
was any talk of an oil embargo, and for reasons which had purely commercial and
no political implications. Some of the know-how consisted of trade secrets, and
the company hoped to be able to sell its technology and hence was interested in
suppressing evidence of how low the profitability and the thermal efficiency of
the plant actually were. Then too, Sasol 1 had a two-track system (ARGE and
Synthol) in the synthetic stage and, since the gas input to the two tracks could be
varied, the yield could be manipulated at different times to produce different
product slates. The plant was not used to produce motor fuels; maximizing the
liquid product yield was not necessarily management's objective at all times; in
the new plants it is.
It must also be remembered that coal is used for two different purposes in coal
conversion plants; part of the coal is converted, part of it is used to provide energy
for the process. The plant also needs electricity which, in South Africa, is
invariably produced by coal, but this is normally not counted in the total coal
input. Furthermore, some of the less useful by-products of the conversion process
are re-run as fuels, other can be re-run if necessary, and this will reduce the
amount of coal needed for process energy. Thus even statistics about the amount
of coal input do not necessarily clarify how much coal is actually being used, at
least not as charge. This is why we feel it is much less advisable to try to judge
the capacity of the plants on the basis of the amount of coal input. This may also
be why the South African authorities are much less reticent about discuss the
coal input. A more refined method would be to estimate the liquid fuel yield by
breaking down the product slate and calculating back from the amount of the non-
fuel parts of the slate. Another possibility would be to calculate sideways, trying
to infer the fuel yield on the basis of the process demands of some other
component, such as water or oxygen. Unfortunately, this can really only be done
by chemical engineers with experience in coal conversion.
One of the main reasons for all of these difficulties is the fact that the Fischer-
Tropsch process consists of two stages, the first permitting much more exact
quantification than the second. If one knows the amount of coal of a certain type
fed to the gasifiers - and their general capacity is well known
- one can easily calculate with considerable precision how much synthesis gas
must come out. In the second stage, however, much depends on such things as the
residence time, the catalyst used, the way the catalyst is fed; in other words, on
the many small details which make up the know-how of those who have been
running the plant for many years. These things being variable and, in addition,
trade secrets, it becomes impossible for the outsider to obtain the same degree of precision about what happens in the second stage of Fischer-Tropsch. In addition, the terminology used by those who claim to know the true figures is not always clear. It is normally assumed that yield figures for "useful products" or "liquid fuels" refer to motor fuels or "CS+" products, but this is not always clear. A further source of difficulty in precise estimation is the fact that some of the less useful by-products can be cracked down to motor gasoline, but their contribution is minimal. For example, it is estimated that about 800 barrels per day of motor gasoline can be produced in each of the new Sasol plants by cracking down tar residues left over from the main gasification process.

One approach to the question would be to start from the capacity of the old Sasol 1 plant, but this could easily be misleading. The liquid product yield of the two new plants must be at least marginally superior to the original one, a conclusion which is dictated by common sense as well as by the fact that the Sasol 1 plant is now being overhauled, probably to introduce innovations designed for the new ones. But even the capacity of the Sasol 1 plant was never a matter of precise public knowledge. For one thing, the gasifiers used were consistently being replaced over the years by bigger and better ones. This increased the amount of synthesis gas which could be converted in the second stage, but it is not as definitive because some of the gas was used for commercial purposes outside the plant. In addition, of course, the yield is ultimately determined by the ability of the synthetic process to convert gas to product, not by the gasifiers' capacity to convert coal to gas. Here much depends on the exact catalyst used, and how they are used, and it is this, we must assume, which was gradually improved over the years as experience and research produced innovations.

A possible approach is to compare the capacity of the gasifiers used in the plants. According to the producer, Lurgi GmbH, the gasification capacity of the Sasol 2 plant is slightly more than five times higher than that of Sasol 1. But even this figure would have to be adjusted upwards for improved technology. On this basis, the figure of 250,000 tons per year of liquid products, of 2 million barrels per year, would give a capacity for Sasol 1 of about 5,500 barrels per day. Indeed, most estimates, including those going back many years, and given by impartial experts unconcerned with the oil embargo issue, oscillate around this figure. Hoffmann gave it as 6,400 barrels per day 42/ and an official report of the United States Department of Energy presented to the United States Senate in 1976 also proceeded from the assumption of 5,000 barrels per day. ±3/ Grainger and Gibson side-step the question by indicating that the plant had a "nominal capacity" of 10,000 barrels per day, but that others put this figure as low as 4,100 barrels per day. Martin Quinlan calculated it to 4,250 barrels per day on the basis of information contained in an old Sasol annual report. The figure of 5,000 barrels per day was accepted by Martin Bailey and Bernard Rivers in their original report to the United Nations Centre against Apartheid published in 1978 and by these authors jointly or singly in later publications on the same subject. 45 The South African authorities themselves have traditionally tried to claim that Sasol 1
produced 10,000 barrels per day, but in compound figures for two or three plants they seem to be giving it a value closer to 5,000 barrels per day. One of the problems in accepting the low figures for the Sasol plants' capacity is of a psychological nature.

For most people in the coal and energy industries it is hard to imagine that South Africa maintained a plant of the size and cost of Sasol 1 for over a quarter of a century just to produce a paltry 5,000 barrels per day. To men whose entire careers have been one long struggle against a narrowing profit margin, this simply a charity and not an enterprise.

Going further, let us briefly review what the South Africans themselves have claimed about the new plants' capacity. The most extreme claim advanced was certainly that of Spandau in a book published in 1978 and characterized by unrealistic claims and figures of all sorts. According to him, Sasol 1 and Sasol 2 would together be producing 112,000 barrels per day by 1981, and further plants coming on stream in the ensuing years would bring total South African production to 312,000 barrels per day by 1987. His figures seem to have been based on a combination of wishful thinking and a misunderstanding about the process itself, whereby 14 million tons per year would be converted at a 1.5 yield rate. Despite the crude and exorbitant nature of this claim, the figure of 110,000 or 112,000 barrels per day has stuck, but it has since been used to indicate the total capacity of all three plants. The 110,000 barrels per day figure presupposes 50,000 barrels per day for each of the new plants and 10,000 barrels per day for the old one. It has been widely used by the Fluor Corporation and thus found its way into business periodicals, particularly in the United States. This is presumably the figure that South Africans have in mind when they speak of 47 per cent or half of demand being covered by the three plants together. This presumably means something like 112,000 out of 240,000 barrels per day or 110,000 out of 235,000 barrels per day. 47/ The total figure of 110,000 barrels per day has been uncritically copied and mentioned en passant in many reputable high-quality publications, including those of the International Energy Agency and the World Bank. A similar claim of 105,000 barrels per day has as recently as 1983 been mentioned in the highly reputable Oil and Gas Journal, but again en passant and in an article basically dealing with something else.

At other times, the South African authorities have advanced other claims, or appeared to do so, with statistics which would convert to very high figures. Thus Sasol in its annual report for 1976 made the claim, later repeated by a government minister, that Sasol 2 would save about R350 million per year in foreign currency. Proceeding from a price of $14 per barrel of Iranian oil and an exchange rate of R1 to $1.15, this would have meant 85,000 barrels per day. This may well be the origin of Spandau's fantastic figure of 112,000 barrels per day for the two plants together. This claim is clearly impossible and may be due to an overly optimistic expectation of yield rates voiced in the 1970s, before the plants were actually operating. At other times, however, the South Africans have used figures which would convert to about 33,000 barrels per day. This figure itself, and the more
precise one of 1.5 million tons per year appeared in the South African business press in 1976 and has been repeated since.49/

A vaguely similar figure, although slightly lower, was given by the South Africans in 1982, 50/ with a lump-sum figure of 28 million tons per year of coal giving a yield of 25 million barrels of oil per year. This would work out to 68,000 barrels per day for all three plants using 76,700 tons per day of coal.

It comes suspiciously close to Martin Quinlan's estimate. It achieves greater credibility because it corroborates fairly well with the figure of 165,000 tons per year of ethylene produced as a by-product, which was mentioned in his source that Rivers and Bailey originally used. It was also used on another occasion by Mr. Sarel J. du Plessis, State Secretary for Energy.51/ An earlier estimate for the production of ethylene was 150,000 tons per year 52/ while Nowacki, a recognized expert on coal conversion technology, gives the wider framework of 150,000 to 200,000 tons per year for ethylene production.53/ If we read this together with Jan Hoogendoorn's figure of 4 per cent ethylene yield from the total slate, 54/ and corroborated by Nowacki, 55/ we can then calculate "sideways" to a liquid fuel capacity of somewhere between 42,000 barrels per day and 56,000 barrels per day. The figure in the middle, 165,000 tons per year of ethylene, works out to 46,000 barrels per day for Sasol 2, which, with the addition of the other two plants, would come close to the officially projected figure of 100,000 barrels per day. At any rate, all of these figures are official of semi-official as they come from people in responsible positions like du Plessis or Hoogendoorn; but they are mutually contradictory to an extent which cannot be explained by routine margins of error.

Approximately the same high figures are also given, albeit indirectly, by Lurgi GmbH, whose exact statistics bear closer scrutiny because they are intended for an engineering audience and also because the company itself is in a position to know the true state of affairs. On the other hand, they are not impartial, as Lurgi is a major supplier of technology and equipment to South Africa and it is in no position to alienate its client by disclosing too many statistics of an unpleasant nature. The company has, in addition, an all too obvious commercial reason for distorting these figures. It basically supplies the gasifiers which produce the synthesis gas and, while it cannot intelligently discharge this responsibility without considerable knowledge about what happens to the synthesis gas beyond this point, its own responsibility ends at the point where the gas is produced. The product yield is the responsibility of those supplying technology for the synthesis stage of the process. It is in Lurgi's interests to suppress information about the poor yield or thermal efficiency of synthesis processes because it stands to lose if hydrogenation replaces synthesis in the future as liquefaction technology. In addition, figures which this company provides occasionally contradict each other. At any rate, Lurgi has claimed that each new plant would use 14 million tons per year of coal, of which 9 million tons per year would be the actual coal charge.

This would produce 2 million tons per year of liquid products, although Lurgi also gives the figure of 2.1 million tons per year. This would work out to between
44,000 and 46,000 barrels per day. This would bring the total to 100,000 barrels per day for all three plants, corroborating with the figure of 4.5 million tons per year which is often repeated by Sasol.

Lurgi also provides information about the capacity of the gasifiers used in the different plants. This permits us to make certain inferences, but it is not conclusive. The capacity of the gasifiers refers to their ability to produce and deliver a certain amount of synthesis gas. This determines the maximum of product that can be produced from the synthesis gas, but not any minimum. If some of the synthesis gas is not used in the process, or if it is used inefficiently, the product yield will be inferior to what the capacity of the gasifiers would seem to indicate. But it is precisely here that one of the most glaring contradictions in Lurgi’s figures goes out. According, to them, Sasol 1 had a gasification capacity of 5 x 10^6 Nm3/d (standard cubic meters per day) while Sasol 2 has a capacity of 26.4 x 10^6 Nm3/d, or in other words, the new plant has a gasification capacity 5.28 times that of the old one. We say “at least”, because we assume that there have been some engineering innovations, that the new plants are more explicitly being built for liquid fuel production, etc. Yet the figures quoted by Lurgi about the yield in liquid products indicate that the output of the new plant is 8.36 times that of the old one, for which Lugi used the figures of 250,000 tons per day or about 5,500 barrels per day. It cannot be asummed that technical improvements could explain such differences in charge/product yield ratios. The figures Lurgi advances would mean that 24,600 tons per day of coal produced 46,000 barrels per day of liquid product, a conversion ratio of 1.87 barrels per tons, which has to be rejected because it is too far above assumptions made by experts in the coal industry. 56/

Lurgi elsewhere speaks of 3 million tons per year of ash being produced from 9 million tons per year of coal, which would either indicate an ash content of 33 per cent or that coal with a 30 per cent ash content is being used, but that a small amount of the ash from the process coal is also being utilized. It is almost invariably assumed that the South Africans are using coal with a 30 per cent ash content. Yet Lurgi elsewhere indicates that its figures were based on coal with a 23 per cent ash content. It further decreases the credibility of its own statistics by presenting in its promotional literature the design for a multi-track plant using Sasol-like Fischer-Tropsch synthesis content. Such a plant is said to have a liquid fuel yield of 1.63 barrels per ton, i.e. barrels of liquid product for every ton of coal; this in addition to the fact that this proposed process has much higher thermal efficiencies because it also provides large amount of LPG and synthesis gas to be used externally. But the liquid fuel yield of the "enhanced" process is lower than the 1.87 barrels per ton which it claims for Sasol 2.

Elsewhere, Lurgi made unsubstantiated claims that Sasol 2 can come very close to target ratio of 1.1 for motor gasoline/diesel in the product slate without impinging on the total liquid product yield. This runs counter to everything that we know about Synthol process technology, which has been described in detail in scientific journals and manuals often enough in the course of many years. It is also belied...
by the behaviour of the South African authorities, who are much more concerned about increasing their supply of diesel than of motor gasoline. Such contradictions seriously impinge on the credibility of Lurgi's data, especially since Lurgi is under contractual obligations to South Africa and has, in addition, its own marketing motives.57/ 

The best impartial calculation is that provided by Martin Quinlan, originally in an article published in the Petroleum Economist in 1978, but which only reached a wider audience when he repeated it in another article in the same publication in 1982. 58/ His reasoning is based on calculating from the assumed yield of the Sasol I gasifiers and by going thence to the yield of useful products (liquids) per unit of synthesis as. The first assumes that 1,000 tons of coal produce 800,000 to 900,000 NM (standard cubic metres) of synthesis gas, which is hardly a matter of dispute since these gasifiers are used in many places outside of South Africa. The second assumption is that for every 1,000 NM3 of gas one derives 118 tons of "useful products". 

is taken to mean liquid motor fuels. This latter figure was an indiscretion made in Sasol's annual report for 1975 before its possible strategic ramifications had been fully appreciated. However, a certain amount of caution is still called for because Quinlan's assumption about the yield of Sasol 1 is extrapolated onto Sasol 2 and Sasol 3. It is not entirely permissible to do so, because Sasol 1 had a two-track system and because the efficiency of the new plants must undoubtedly be higher than that of the original one. In addition, his calculations are based on the total coal input, and not on the charge. The first error would tend to underestimate the capacity of Sasol 2, but the second one would more than outweigh it by vastly overestimating it. 

At any rate, calculating from the figure of 2 million tons per year of coal, he arrived at 4,250 barrels per day for Sasol 1 and extrapolated a 31,000 barrels per day product yield for Sasol 2 from 14.6 million of tons of coal per year. He then deduced a slightly higher capacity for Sasol 3 by taking the figure of 32 million tons per year as total coal consumption. This has been quoted in Sasol's annual reports and in the South African Yearbook for several years in a row. He concluded that Sasol 3 must have an output of 32,750 barrels per day, thus bringing all three plants up to a total motor fuel production of 68,000 barrels per day. Despite what we think were errors, this figure is not all that improbable, because it approximates the figure of 33,000 barrels per day capacity for Sasol 2 divulged by the South African press before the laws on publishing this information became more stringent. If his conversion of 118 t/1,000 Ni3 is applied to the charge, it means that the two new plants have a capacity of about 25,000 barrels per day each. Quinlan's figures are the most credible we possess because they are both knowledgeable and impartial; nonetheless, no one should fear ridicule if he were to cite the lower figure of 25,000 barrels per day at a seminar of petrochemical engineers. 

The details of Sasol process technology occasionally contain other suspicious contradictions. Lurgi claims that each of the two new plants requires 14,000 tons
per day of oxygen, which would bring the total oxygen requirements of all three plants to about 30,000 tons per day. Yet the Ralph M. Parsons Company in the United States has designed a Fischer-Tropsch plant with a capacity of 100,000 barrels per day. It would use 50,000 tons per day of oxygen. Obviously, differences in the feedstock and in other conditions make it impossible to compare these two directly, but it is hard to see how differences in the type of coal, process design, and other factors could really lead to such a wide discrepancy. This could presumably be taken as evidence that the total capacity of all Sasol plants is closer to 60,000 barrels per day than to 100,000 barrels per day. Detailed scrutiny of Sasol's published data by engineers and scientists with a background in carbochemistry would probably bring to light many more such contradictions and/or permit more refined estimates of the total capacity.

The South Africans themselves may also have realized that indiscreet disclosure of certain details and/or promoting absurd claims may stimulate critical analysis of the question. Shortly after the aforementioned article by Quinlan in the Petroleum Economist was picked up and summarized by Quentin Peel in the Financial Times, the South African authorities seem to have come to the conclusion that it would be in their interest to stay off the subject in print. Thus the 1983 issue of the South African Yearbook, a propaganda flyer on the South Africa's supposedly impending energy surplus published by its embassy in Washington, as well as a paid advertisement supplement in the Wall Street Journal, which did not spare any minor detail or statistic in relation to electricity, coal or chemical products, passed over the question of the Sasol plants' capacity in complete silence. Around the same time, the authorities charged a high-ranking naval officer with passing state secrets to a foreign country. He is assumed to have known the exact capacity of the plants. As a result, the minority Government must reckon with the probability that "significant others" already know the true picture.

At any rate, the extremely contradictory and occasionally absurd claims which the South African authorities and their collaborators have made in the past seriously reduce their credibility. We are at present in a lull when activity and interest in synthetic fuels and coal conversion are at a low point because of the fall in the price of oil and in the demand for energy. Hence no one in the energy industry is really very interested in questioning the figures which the South Africans supply on the Sasol plants' capacity. In the United States in the 1970s, the adherents of competing technologies had no qualms about criticizing Sasol technology and belittling its suitability, though at the time the question of the plants' capacity had no strategic relevance to anyone and they tended to attack Sasol technology more on the grounds of thermal efficiency and cost. Synthetic fuel projects are now being shelved; the issue is less relevant. Should it become relevant again, however, we can assume that the suppliers and salesmen of competing coal conversion technologies would then find it necessary to knock down South Africa's official claims on this score. Then we would hear about it from experts in much greater detail and with much more stringent scientific precision.
In the meantime, we should proceed cautiously on the assumption that each of the two new plants has an output of liquid fuels, including motor gasoline and middle distillates amounting to somewhere between 25,000 and 36,000 barrels per day. Adding to this a further 6,000 barrels per day for Sasol 1, presently being overhauled, this would put the total South African synthetic motor fuel production capacity at between 55,000 and 78,000 barrels per day. Operationally, an estimate of 70,000 barrels per day would seem easiest to handle. What this implies for the oil embargo will have to be judged against other estimates of two other quantities: domestic product demand and stockpiled reserves. It is, however, immediately clear that this production capacity falls far short of what South Africa needs to withstand an effective oil embargo. At any rate, these estimates are also deliberately pointed upwards rather than downwards, for two reasons: for one, it is strategically prudent to proceed on the assumption that the enemy is better armed than he actually is; for another, accepting the lower figure is psychologically difficult for most people who are used to thinking about enormous high technology projects of this sort in the context of profitability or cost-effectiveness. The lower estimates imply levels or cost-effectiveness which would deter most decision-makers from building the plants at all.

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G. THE SASOL PLANTS AS AN INVESTMENT

Coal liquefaction is one type of coal conversions coal conversion is in turn a subcategory in the broader field of synthetic fuels. Coal liquefaction of the type used in South Africa is also a form of petroleum substitution. Of all synthetic fuels and petroleum substitutes currently being considered, coal liquefaction has received much less attention than other coal conversion technologies. For economic reasons, it is at present under serious consideration only in South Africa. But it remains in the background. In the 1970s, the industrialized countries became interested in petroleum substitution for obvious reasons, and debates erupted among the developers and salesmen of a variety of different petroleum substitutes and methods of producing them. At that time, the small Sasol 1 plant was the only commercial-size plant anywhere in the world producing motor fuels from coal. The only argument that could be advanced for its technology was a strong one, to wit that it was available. Hence proponents of competing technologies had concrete interests in criticizing it, and they did so quite widely in a number of places, especially in the pages of scientific journals and in front of parliamentary committees. Proponents of completely different approaches, such as the use of oil shale or tar sands, had little reason to attack it; it was more those companies selling hydrogenation methods of coal liquefaction which took up the cudgels against it.

We will therefore review some of the things said about it by coal conversion experts in order to be able to evaluate the decision by the South African Government in the light of purely technical considerations. Since most of these comments are critical, it should be said at the outset that there has been much greater receptivity to Fischer-Tropsch technology as a method of producing feedstocks for chemicals rather than for motor fuels. It should be borne in mind
that what is being discussed in the following pages refers almost solely to motor fuel production. 63/

It was almost an article of faith among those who commented on it in the 1970s that Fischer-Tropsch technology was never profitable except under certain "extraordinary" circumstances, partially a reference to the Second World War, occasionally a reference to low-cost coal and labour in South Africa. Some disputed the profitability of Sasol technology altogether and under any conditions, others dismissed it more charitably as profitable in South Africa but nowhere else. Thus one American expert with the Ralph M. Parsons Co. in California wrote: "Fischer-Tropsch technology has been practised on an industrial scale in several coal-based economies. However, it has never been practised successfully in an economy where its products faced open competition from indigenous or unrestricted low-tariff importation of crude oil." §/ Questioned by a United States Senate committee investigating different synthetic fuel technologies, a representative of the M.W. Kellogg Co. which had developed Sasol's Synthol technology, admitted that it would not be feasible in the United States. §/

In the Federal Republic of Germany, Prof. Helmut Pichler, who had been an assistant of Fischer and Tropsch in his youth, was similarly negative in a report to the Federal Ministry of Research and Technology in 1970. He compared coal liquefaction under the economic conditions of the Third Reich

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and in the United States, South Africa and the Federal Republic of Germany in the post-Second World War period. He found that, at that time, producing motor gasoline from coal would cost two-and-a-half times as much in the Federal Republic of Germany as it did in South Africa. 66 Ten years later, another study conducted by the same ministry together with the oil company Veba also concluded that liquefaction would not be economic in the Federal Republic of Germany at the time. 67/ Another expert from the Federal Republic of Germany, Theimer, a great whole-hogger for coal conversion in general, was no fan of Fischer-Tropsch. He said: "The proponents of Fischer-Tropsch synthesis are able to point to its success in South Africa, but the conditions there, especially cheap coal and cheap labour, are not reproducible in Europe. Calculated in thermal quantity, German hard coal costs seven times as much as South African, and cheap German brown coal three times as much." .&/ He also stressed that the profitability of this technology in South Africa rested on a tacit tax subsidy. He estimated that in the Federal Republic, Fischer-Tropsch motor gasoline would cost twice as much as that produced from crude oil; the same produced from lignite would fare better, but would still not be commercially viable. §/ Grainger and Gibson, elder statesmen of the United Kingdom coal industry, were more discreet and charitable but exuded skepsis about Fischer-Tropsch. According to them, large reserves of low cost coal and difficult access to oil have made it feasible. 79/ Expert studies conducted in the United States, both by the United States Department of Energy, as well as by the equivalent authorities in the states of Kentucky and Illinois, have also found that Sasol technology would not be compatible with United States costs or coals. 21/ And with further reference to its
use in a methanol plant in Modderfontein in South Africa not belonging to Sasol Ltd., the two aforementioned British experts said that in "in most, if not all of these cases, however, there are special features of a strategic or policy nature which obscure the economics and make it difficult to translate them to Western conditions." 2/

The major point in which Fischer-Tropsch liquefaction technology has been found wanting has been that of so-called thermal efficiency. Thermal efficiency is the energy value of the hydrocarbons left over after conversion as a percentage of the same in the original coal. Sasol-type Fischer-Tropsch is generally held to have a thermal efficiency of 40 per cent when judged on the basis of the motor fuels alone. Its thermal efficiency is given as 58 per cent if the methane gas produced in the process can be used. More precisely, for every joule in the liquid fuel coming out of the plant, 2.5 joules of coal must go into it. Other methods of coal liquefaction invariably have higher rates of thermal efficiency, synthesis methods staying in the range of 45 to 49 per cent, hydrogenation methods falling in the range of 56 to 62 per cent. 23/ Even lower thermal efficiency values have sometimes been given for Fischer-Tropsch; thus Nowacki in certain places puts it as low as 35 per cent or even 32 per cent for liquid products, i.e. no methane. The other technologies, according to him, all had higher rates, MTG having a rate of 44 per cent, the remaining ones ever higher. 74/ He states: "The conclusion shown by the cost indexes is that the Fischer-Tropsch process has a severe disadvantage. If methane gas cannot be used or sold and the other by-products are not usable, the technology is vastly uneconomic".

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Grainger and Gibson also confirm that Fischer-Tropsch probably shows a thermal efficiency of 40 per cent for motor fuels alone, 60 per cent if the methane gas is sold. 25/ A table from Grainger and Gibson is reproduced below. This clearly shows that Fischer-Tropsch has about half the thermal efficiency of the H-Coal and SRC1 and SRC2 processes. A restatement of the same thing in more monetary terms is given by the same two British scientists when they say that, at the time (1979), when the coal price in the United Kingdom was £30 per ton, the break-even point for operating a Sasol-2-type plant in their country would be at a coal price of £8 per ton, and for a plant operating on the H-Coal process it would have to be £19 per ton. This demonstrates two things: the extent to which Fischer-Tropsch is uneconomical when compared with other possible liquefaction technologies, as well as the extent to which it is totally uneconomical in a European country. 76/ At the behest of the United States Department of Energy, the Ralph M. Parsons Co. also conducted a cost-feasibility study comparing four synthetic fuel methods. Fischer-Tropsch was found to be the third highest in cost on almost all points. It has to be noted, however, that the study was based on the assumption that captive mines could be used and thus abstracted from the problem of coal price. 77/

CAPITAL COST AND THERMAL EFFICIENCIES for different coal liquefaction processes

<table>
<thead>
<tr>
<th>Process</th>
<th>Capital cost</th>
<th>Efficiency</th>
</tr>
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(Q/KW output) (%)
First Generation
Lurgi-SNG 244 59
Sasol 2 455 34
Second Generation Synthesis
FT-Slagger 293 48
Methanol-Slagger 247 57
Mobil M-Slagger 292 52
Second Generation Hydrogenation
EDS 249 64
H-Coal-FO 161 74
H-Coal-SD 206 69
SRC1 196 70
SRC2 226 70

Nowacki cites the following four advantages for Fischer-Tropsch technology: (a) coal properties are not important; (b) product composition is controllable; (c) the product is free of nitrogen and sulphur; (d) the technology is commercially available. Of these four advantages, the third is irrelevant in South Africa, the second is mitigated by the fact that the product composition with Synthol is not the one really desired by the South African authorities, while the other two advantages remain valid. In fact, the only thing which can be said for the use of Fischer-Tropsch technology in Sasol is that this technology alone is immediately usable with low-quality high-ash coals of the type found in South Africa. According to the same expert, the same technology had the following disadvantages: (a) the coal must be gasified with oxygen or steam and must be recombined and purified, i.e. it requires a great deal of heat and preparation; (b) it is connected with high capital costs; (c) its thermal efficiency is too low. This expert was much concerned with the question of by-products and consistently argued that a technology such as the Fischer-Tropsch could only be competitive, if at all, when gas and other products could be used. Since he knew this could hardly be the case with mammoth plants whose by-product outputs vastly exceeded demand in small markets, he surmised that many by-products would simply be used as fuel, which is thermally very wasteful. He was further skeptical of Fischer-Tropsch because compared with other processes, it used huge amounts of electricity.

The question of the thermal efficiency of this process is not an abstract nicety to be debated among process engineers. Low thermal efficiency means that a country's resources are depleted faster to produce the same effect in fuel or energy. For example, if the South African liquefaction plants ran on a hydrogenation technology, and not on Fischer-Tropsch, they could produce the same amount of motor fuels with 21 million tons per year instead of 32 million tons per year, a saving of 275 million tons of coal in a period of 25 years of useful
life of the plant. Others have brought up another criticism of Fischer-Tropsch, namely that the resulting motor gasoline is low in octanes and requires complex refining to be upgraded to normal standards. 80/

It has also been argued that coal liquefaction technology, even if less suitable for technical reasons, might still be preferable for social reasons. This has often been brought up in Australia, but the example used there would hardly apply to South Africa. Since liquefaction presupposes labour-intensive domestic coal mining, it is held to stimulate employment in the mines, as well as elsewhere, even though the liquefaction plants themselves are not labour-intensive. This argument is understood as being in contrast to the importation of crude oil. In South Africa, however, mine labour is black; it could hardly be the intention of the minority Government to stimulate employment among miners. Since they are largely underpaid migrants, keeping them employed does not have the same effects in maintaining demand standards as it would in Australia. This argument, if it had any validity for South Africa, is more likely to be advanced by a post-apartheid Government if it decides to retain the plants.

The gist of much of the evidence tendered by experts is that coal liquefaction is permissible for other than profit reasons in other than profit-orientated situations, generally for public utilities or in case of strategic necessity. Thus one researcher for Shell Coal writes: "Such an analysis leads to the conclusion that coal gasification and liquefaction could be developed as a utility type industry under rather tight government control. This has its strategic advantages with respect to stability and security of supplies. On the other hand, it may discourage private industry from getting involved in this business. Much will therefore depend upon the political decision-making process and that maybe is one of the biggest unknowns left in answer to the question when coal conversion will become of economic significance". 81/ This would indicate that technology used by Sasol would not be profitable in a situation where the country had free access to foreign crude oil.

In 1975, Sasol's founder, Dr. Rousseau, admitted much of this in a lecture in the United Kingdom. He pointed out that Sasol 1 had been built in the 1950s, when crude oil cost $1.3 per barrel and when coal cost $0.6 per ton. In the two decades following, oil remained stable in price while capital and labour costs increased, thus making further expansion of the original Sasol plant uneconomic. After the 1973 oil crisis, oil rose to $11 to 12 per barrel and coal to between $4 and $5 per ton at pit-head in South Africa and the plant became "marginally profitable", although it would still not be "attractive for private investment". He admitted that oil-from-coal could never compete with Middle East oil in other countries, but said that motor gasoline produced by Sasol 2 cost only 25 per cent more than if it were produced from offshore fields in South African waters. Grainger and Gibson charitably add: "These statements explicitly confirm the subjective elements in cost assessment". 82/ Dr. Rousseau in the same lecture openly talked about something else which was brought up widely in South Africa in the 1970s, when the business community was trying to stave off the proposed
new Sasol plants; the plants operate on captive coal bought from their own colliery at nominal price. He admitted that it would not, in fact, be profitable with an export price of $10 to $15 per ton of coal; in other words, even his reserved remarks about the "marginal" profitability of Sasol 1 were based on an artificial price of between $4 and $5 per ton of coal. 83/

How much, then, does motor fuel from the Sasol plants actually cost? Based on recent estimates for the cost of various synthetic fuels expressed in barrels of oil equivalent 1/ and ranging between $50 per barrel and $75 per barrel, it is our estimate that the higher figure is more approximate because allowances must be made for an opportunity loss of between $10 and $11 per ton for coal bought at captive prices. An additional argument for the higher cost estimate is that this motor fuel is produced from one of the most inefficient and uneconomic synthetic fuel technologies, and that the methane gas from the plant is reformed rather than sold to outside users. In fact, the claim that Sasol was vastly profitable has never been advanced anywhere except on a single occasion by a consultant for Fluor Corporation, a certain R.W. Johnson. §/ The South African authorities made certain attempts to suggest this in the 1970s, but retreated into prudent silence after 1980.

Let us briefly review relevant comments by a few other scientists and engineers. Mr. Nene of Gulf Research has compared Fischer-Tropsch synthesis and three other processes and found that it has the lowest cost-effectiveness of them all; it was, in fact, one half that of the cost-effectiveness of the two foremost technologies in his comparison. 1/ Eisenlohr and Gaensslen, who work for Lurgi, have found its thermal efficiency to be 40 per cent by itself, 58 per cent with co-production of pipeline gas. This is the lowest thermal efficiency of all tested technologies. As far as investment costs go, it has the highest cost of six processes on the criterion of energy, the second highest on the criterion of weight. 87/ Professors Jintgen and Schulze of the Technical University of Berlin and Dr. Wiegand of Bergbau-Forschung GmbH have stressed the poor quality of the motor gasoline produced by this technology and its need of additives for upgrading, as well as the fact that the thermal efficiency is much lower than that of hydrogenation technologies. In addition, its product slate is too broad and it is only said to be usable in South Africa because of the type of coal found there. Since its production costs for motor gasoline are much too high, it would be somewhat more economic for producing diesel, but this presupposes new methods as yet undeveloped. 88/

Mr. Gray of the Mitre Corporation in the United States believes that Fischer-Tropsch has no future outside of a new technology known as K61bel synthesis reaction which produces a greater yield of liquid products at the same capital costs. 89/ Mr. Riekena of UOP Inc. in the United States found in 1981 that of four different Fischer-Tropsch processes, the entrained-bed type used by Sasol has the lowest thermal efficiency. In its favour he could point out that it was more economic in its use of catalysts. This study had been done for the United States Department of Energy. 90/ Mr. Singh of the United States General Accounting
Office argued that the low profitability of Fischer-Tropsch technology in South Africa resulted from the fact that that country could not use greater amounts of methane and reform it back in the plant to SNG. Since this condition would not apply in the United States where methane is easily marketable, he argued that a Fischer-Tropsch plant in the United States could still be reasonably profitable. 91/

Mr. Simbeck of the Synthetic Fuel Association in the United States joined in the same debate from the other side, arguing that Fischer-Tropsch technology has considerable future for it, but not the type of Fischer-Tropsch used by Sasol. 92/

Others have also argued that Fischer-Tropsch could be profitable if the methane could be marketed or used. 93/

Indian engineers also once conducted a feasibility study and found that Fischer-Tropsch would only be economic in India in huge plants. This is all the more interesting because Indian coals are very similar to South African coals, and the country also has a low wage-base. 94/

In a large report done for the United States Department of Energy in 1980, Prof. Penner of the University of California at San Diego and his group rejected Sasol-type Fischer-Tropsch technology because of its poor product quality and because of the yield pattern. Since the high costs and inefficiencies of the process were all in the gasification stage, they argued that synthesis would always be more costly than hydrogenation because it requires much more energy to break down coal molecules. 2/

Two other United States university scholars have argued that inflation over time is making any kind of liquefaction technology less feasible, although they have done so on grounds that we could hardly agree with. 96/

Francine Stock of the Petroleum Economist has also dismissed Fischer-Tropsch as too inefficient and unlikely to be used outside of South Africa. 27/

Finally, a French conference in 1976 had found that no coal liquefaction process would be profitable in Europe before the beginning of the next century. 98/

The international scientific and engineering community is almost unanimous in its low opinion of Sasol's technology.

Why then did the South African authorities choose this technology? The answer is simply that it was the only one available; that they had no choice in this matter, as in many other ones; they were pressed for time; and they had no possibility of creating something else with their own research and development potential. They did have a certain know-how and personnel to run these plants, for they had been running a similar one for many years. But they had no potential to design or build the plants, and would have been worse off if they had had to enter large-scale coal liquefaction with plants operating on a technology with which they had no experience. In addition, there is the very potent argument that their coal has a very high ash content and hydrogenation methods available are still unable to deal with this problem. Potentially, a solution to this problem can be found, but it must be found by researchers outside of South Africa. The minority Government, however, was pressed for time.

However excusable South Africa's decision may appear against this background, its long-term effects are considerable. The plants have a useful life of at least 25, and possibly 50 years. The thermal efficiency is low; year after year
they will be gorging themselves on the nation's coal reserves at a rate which could have been avoided. The minority Government may or may not have been fooled by delusions about the contribution which the by-products would make to the profitability of the entire plant. Because of its enormous size, the complex produces large quantities of by-products which have no real price because they are there for the asking; some of them are hazardous. But being there anyway, they will now be used as chemical feedstocks for chemical industries. 

Presumably, some of the methane could be used as industrial fuel. In the long run, Sasol may provide a subsidy for the development of a chemical industry, but in the meantime, the country is saddled with large amounts of ammonia, going beyond what it can use for the production of fertilizers especially because the latter now have a saturated market anyway. In addition, there was an ethylene surplus in 1983, and in the same year Sasol Ltd. was obliged to dump large amounts of acetones abroad because a chemical factory, which was going to take them as feedstock, had not been finished on time. South Africa also started exporting large amounts of tar acids, its own market for this being totally saturated.

If and when South Africa learns to use the by-products rationally, a certain modest boom in the chemical industry can be expected. The Government is encouraging this development for strategic reasons as well. This is one reason why Sentrachem Ltd. may be considering participation in the next coal liquefaction plant. That company may also want to get a hold of a cheap feedstock source from the by-products of liquefaction. At any rate, not only will South Africa move towards self-sufficiency in chemicals, Sasol hopes to raise its general profit level by entering the field. In late 1982, Sasol announced that it would be expanding downstream into chemicals. 

If chemicals should become a new area for South African economic expansion, this would further rearrange the country's position in the constellation of transnational corporational patterns; the reason is that South Africa's chemical industry has always been dominated largely by British-owned companies. But even here it can be pointed out that the profitability of an expanded chemical sector - if this does come about - would also rest on an artificial basis: one, government protection for strategic reasons, two, cheap feedstocks coming from the Sasol plants. At the basis of all of this is the low pit-head price of coal due to the poor pay of the black miners. If this latter foundation for the entire system should ever be removed, all profitability structures on top of it will collapse.

It thus becomes apparent from the above that coal liquefaction, as it is done in South Africa, has the character of a public utility, operating on strategic considerations in order to supply a profit-oriented economy, but not bringing any profit itself. In fact, it must be operating at considerable loss and this loss must be compensated directly by the Government, although we do not know exactly where or how this is done. Seen in terms of the global economy, the profits of everything else have to be raised in order to produce the social surplus profit to hold up the
unprofitable coal liquefaction plants. One way in which this is accomplished is with the low-cost labour used in the mines. But this is a transient factor, it is already coming to an end; in the post-apartheid economy it will disappear altogether.

The second sine qua non for this situation is the oil embargo, which is also transient. It is only in South Africa's interests to produce motor fuels in this manner, with this plant and technology, and at this loss, because it has an artificially restricted access to crude oil on international markets. But this is the result of the apartheid system. What happens if and when it falls? We get a small glimpse of this coming dilemma even now. The South African authorities have still not been chased off international oil markets, since the embargo is not stopping the oil flow to South Africa but only raising its price and complicating its logistics. South Africa can still buy crude oil at $5 per barrel over spot. The motor fuels refined from this are still cheaper than those produced by the Sasol plants. Hence, as long as it has access to some crude oil on international markets, South Africa can save money by buying it, perhaps storing it, and foregoing purchases from the Sasol plants. This reduces the throughput in the plants. As the throughput goes down, the cost per unit produced rises rapidly, because cost calculations unprofitable as they are already - are geared to normal operating throughput levels. About one-third of the price per unit of product is due to fixed capital costs anyway. In other words, there is a trade-off between what they can save in one place and what they can save in the other. This is a foretaste of bigger problems to come.

When apartheid falls, there will be no further rationale for the oil embargo, and no further rationale for the Sasol plants. The dilemma facing a post-apartheid Government will be to decide where it is to absorb an all too certain loss: by running the plants and foregoing cheaper crude from abroad, or by purchasing cheaper foreign crude and writing off the plants. The decision of the minority Government to build the plants leaves the country stuck with enormous capital plant with a useful life of at least 25 years. The regime was driven to diverting investment into this unprofitable sector for strategic reasons in order to save the system which has put the minority into power, but it has acted against the global interests of the national economy. In the long run, the regime has emburdened its national economy with capital plant equipment of a very costly nature which has no rationale outside of the present transient political context. The minority Government has two conflicting responsibilities: it has the responsibility for global national economics and the economy's long-term development, including responsibility for the rational use of non-renewable natural resources; it is also responsible to its own proper political constituency, the country's minority of white inhabitants, to protect and enhance their economic interests. Where these two responsibilities collide, it trades off the latter against the former. The value of the Sasol "investment" from the latter point of view is dubious, since it does not appear that it will have a decisive impact on South Africa's ability to withstand a rigorous oil embargo.
Since it produces somewhere between 5 and 10 per cent of the total energy demand of the national economy but costs around $5.8 billion in capital in an economy with a Gross National Product of around $80 billion, it is an "overinvestment" in national economic terms. In narrowly capitalistic terms, it is not an investment at all since it operates at a loss. In addition, coal liquefaction also accelerates the depletion of the country's coal reserves at a higher rate than what is necessary. The white minority in South Africa has a long history of such short-sighted and wasteful economic habits. Two centuries ago they started overgrazing the land, disturbing the water supply and ruining the soil; they also killed off the fauna too fast. More recently, they have been developing a specialized mineral mining sector at break-neck speed and selling off the output at artificially low prices to foreign consumers. There is an additional consideration. Overspending on the Sasol plants, like overspending on military activities, etc., increases the rate of inflation in the country; this decreases the relative profitability of the plants even further. The reason is that the alternative against which profitability is judged, is internationally purchased crude oil. If South Africa's inflation rate is higher, the relative disadvantage of using coal via liquefaction becomes greater.

There is only one condition under which these plants could become profitable in the future and that is if there is an enormous increase in the oil price. But the oil price would have to at least double from its present level before this effect would come about. The profitability of coal conversion depends on a complex relationship between the price of oil and the price of coal, both taken internationally, but a steep rise in oil prices also pulls coal prices up. The gap - the advantage of using coal - would have to increase beyond where it is today before the Sasol plants could become profitable in these terms. No one expects this to happen until well into the next century.

In other terms, they can never be profitable because the technology used is the most antiquated and least efficient of all coal liquefaction technologies which will then be available. This is because the South African authorities precipitously chose the then antiquated Fischer-Tropsch Synthol technology instead of waiting another 10 to 15 years for a better one to be developed. Their own delusion is that they are better off for strategic reasons with a form of autarchy. They have had some success in convincing themselves and their white constituency that Sasol coal liquefaction saves foreign currency because they do not have to import crude oil. First of all, more than half of the formal saving is immediately eaten up because it increases foreign currency drains due to other aspects of the same project. But they are ultimately producing at a much higher cost than if they were spending the foreign currency to purchase crude oil abroad. The white minority Government claims that it is defending the free enterprise system. It is nevertheless difficult to see how the South Africa's entire energy policy can possibly be squared with normal capitalistic considerations.
We might briefly risk a rough estimate of what we think the cost of this policy has been. Let us assume that the plants produce motor fuels at $75 per barrel oil equivalent. This assumption is not extreme on the basis of what we know about synthetic fuel costs elsewhere. It also includes the opportunity loss on the captively-purchased coal. Let us further assume that South Africa Produces 70,000 barrels per day of its own synthetic fuels, and purchase the rest on the spot market at a "pariah penalty" of $5 per barrel over spot. Furthermore, there is an opportunity loss on strategic reserves in storage, as we will discuss elsewhere; and let us make the final assumption that the Sasol plants and the storage facilities have together cost $6.4 billion, of which only $1 billion has as yet been paid; the rest bears interest at the same assumed rate of 12.5 per cent (1.5 per cent over Libor at present). This means that South Africa incurs an opportunity loss of $1.175 million on Sasol production. The South Africans then pay an additional $383 million in "pariah penalties" for foreign oil; they then have storage losses of $480 million and have to pay $660 million in interest per year. This brings the total annual loss due to their energy policy to about $2.7 billion; this excludes the question of capital investment losses, it is simply the annual operating loss.

In 1982, South Africa had a Gross National Product of $78.9 billion, very poorly distributed internally, and external public debts of $23.7 billion. How long is such an economy in a position to take a beating of this magnitude year after year? The South African authorities themselves put the cost of the war in Namibia at $1 billion per year, the cost of carrying the settler community there at another $500 million annually. These figures show the extent in monetary terms of the costs of these policies to the national economy. We will not even go into a discussion of intangible disbenefits. Furthermore, at this enormous cost it cannot be argued that the oil embargo has been "totally ineffective". A country which has to restructure its energy sector in such a radical manner, at such a high cost, and from a position with so few options, would not seem to be a very suitable place for investment. It would seem to be much better suited as a potential customer, and especially, a borrower of money. The Western business community has gradually come to realize this, hence more and more selling and lending to South Africa, less investing there.

In this paper, we are confining our task to a purely technical and economic evaluation of the Sasol plants and assiduously avoid discussions of any social questions. There is one point, however, where we think a digression from this might be allowed: the claim by the minority Government to have enormous underground storage facilities, storing up to several years' worth of crude oil. If all this be true, then South Africa seems to have been an absolute pioneer in strategic petroleum storage, far ahead even of the Great Powers in the extent and technology of their storage, and by now the soil of their proverbially retrograde Fatherland must have the greatest density of underground storage facilities anywhere on the planet. This is a cruel irony because one of the most striking features of South African economy to outsiders is that it has thus far failed to organize a reliable supply of water for its own soil.
Water, one of the most elementary economic factors, is not even available in sufficient volume. The white minority Government is less concerned about this problem, since it basically affects the black majority, whose less fortunate rural dwellers must spend much of their time walking their children and their cattle considerable distances from their homesteads to the nearest water source. Could it be that they are trudging over mankind's densest and most advanced system of underground petroleum storage facilities, put there to defend the system that cannot even manage the water supply properly?

There is another consideration of a social nature. It can be argued that, in the promotion of coal liquefaction and the construction of the Sasol plants, the white minority has itself been exploited. If the production of motor fuels from coal is not profitable to South Africa, it has been enormously profitable for Lurgi GmbH and Fluor Corporation. In this way the South African Government is providing much needed research and development funds for synthetic fuel industries in the OECD countries. In addition, it has to pay high interest to international banks on its over-borrowing in connection with the plants. The white minority here sucked into an incredible overinvestment, egged on by companies in the industrialized countries that wanted to gain experience and know-how in mammoth projects (just think of L'Air Liquide) and maintain momentum in coal conversion technology until it became profitable in their own countries. The minority Government has increased its dependence on the OECD for capital and technology. In return, it received only small amounts of technology to run the plants. It must also deplete its coal reserves at unrealistically low prices - another subsidy for the OECD - and its need to rapidly develop and expand extractive export industries to pay for all these extravagances brings South Africa not forward, but backwards into the same tragic circumstances that produced its racist system. As all these complications begin to close in on the white minority, apartheid even ceases to be profitable to them, although it is still very much so for Fluor and Lurgi. Even if we were to take the charitable view that the poor misunderstood racists are not trying to defend anything as crass or ignoble as pigment prerogatives, but are sincerely motivated by a desire to maintain a free enterprise and market-oriented economy - as they themselves claim - we would have to judge their prospects for doing so to be bleak in view of the decidedly uncaptialistic basis on which coal liquefaction is being conducted.

H. DEMAND, STOCKPILING AND SASOL’S IMPACT ON THE OIL EMBARGO

South Africa's current domestic demand for refined products must remain a matter of conjecture because any statistics bearing on this question have been declared secret since 1979. The last year for which we possess a certain amount of clarity was 1978, and all conjectures are based on changes occurring since then, some of which must of necessity counteract each other. A more precise breakdown was given by Bailey and Rivers in 1979. 100/ Estimates of current demand must be made from the estimated adjustments - conservation
and/or growth - of these figures in the last five years. At present, estimates range from 250,000 to 320,000 barrels per day. Our own estimate is about in the middle of this range and it is arrived at on the basis of the following projections. When faced with a crisis in their oil supply in early 1979, the South African authorities opted for functional rationing, which was not rationing in the narrower sense. No individual allotments of petrol or other refined products were made, rather a programme of conservation was instituted, the bulk of which was apparently obtained by severely limiting the number of hours filling stations could remain open for sales to the public, as well as by raising the price of petrol for the private consumer. This conservation programme coincided with a certain slowdown in the economy which was able to reinforce it. The figure of 20 per cent savings in oil has been widely quoted and it is not improbable, both with reference to the South African background and with reference to similar experiences elsewhere. As far as private, or consumer petrol demand is concerned, prior to 1979 this demand probably did include a significant margin of pure waste. There was probably much less of this in industry, and agricultural demand probably had no conservation margin to it at all. Weighing this for the significance of different sectors, it is safe to translate a 20 per cent reduction in elastic demand with a 15 per cent reduction in global demand.

Adjusting the 1978 statistics for this reduction would then provide us with a figure for the level of demand as it was in late 1979; since that time it has undoubtedly risen, if for no other reason then because the number of motor vehicles increased, particularly in 1981. In fact, one of the few vaguely usable statistics which have come out of the South African authorities via an indiscretion was that around 1982 petrol consumption was rising at 1 per cent per annum, while diesel consumption was rising at 4 per cent and global consumption of liquid fuels at close to 4 per cent. These figures are credible because they are not improbable. They also strengthen the impression that the minority Government has been able to contain demand growth for petrol, but not for diesel. The latter is due to the fact that there is a gradual switch from petrol to diesel-driven vehicles over the long term, a trend which could not be brought to a complete halt at once, and which was desirable for other reasons. If we use the figures provided by Bailey and Rivers in 1979 as a point of departure and adjust for re-export, stockpiling and the consumption of refinery fuel, we would then have a net product consumption of 273,000 barrels per day in 1978, which is reduced by 15 per cent at the end of the following year - 230,000 barrels per day and which then rises 4 per cent for every year thereafter. This will put current South African product consumption at around 280,000 barrels per day of refined products. This figure might also be prudently cut by another few thousand barrels per day to allow for the fact that less petroleum is being consumed in refinery operations because the total refinery throughput has decreased. At any rate, we will proceed, operationally, on the assumption that domestic demand is now at about 280,000 barrels per day.

In order to gauge South Africa's ability to withstand an oil embargo over a period of time, we must know three things: Sasol production, total consumption, and stockpiled reserves. And it is the third variable which is the most difficult to
assess because it has always been the matter of secrecy, but also the object of
deliberate disinformation attempts. A more precise and reliable estimate would
require a study in its own right and would be well

outside the scope of this present report. However, in order to provide some
reliable estimate at the present time, even on the basis of very imperfect data and
isufficient research, a few things would have to be said about strategic stockpiling
of petroleum. Since the early 1970s, the South African authorities themselves
have claimed to have large reserves in stock, normally said to be several years'
worth of supplies, and, more precisely, three years is the figure often cited.

Beyond this, rumours floated in the early 1970s, repeated many times since and
have further elaborated that most of this stockpiling is done in underground
storage facilities, very often "disused mineshafts". This particular cliché was
being used in the early 1970s, long before the present crisis. It has been
swallowed uncritically by the South African white minority, and it is occasionally
repeated in the oil industry, though less uncritically.

Thus, in July 1982, the most widely read daily newsletter in the
international oil industry carried a rumour that Israel and South Africa had
together stockpiled 150 million barrels of government-owned strategic petroleum
reserves, said to cover three years of South African supply and one year of Israeli
supply. 12/ The occurrence of rumours like this is probably a concrete
disinformation ploy on the part of the South Africans, but it may coincide with
other groups' peculiar interests; the amount in question is more than enough to
influence the price if portions of it are dumped. Hence, oil traders may have had a
subsidiary interest in helping the South Africans float this rumour. The rumour
was itself inaccurate because three years of South African and one year of Israeli
supply would be a multiple of the figure quoted. In 1979, Bailey and Rivers had
been aware of this South African claim of three years and had subjected it to
critical analysis and come to the conclusion that South Africa probably stockpiled
about half that amount. They have normally made generous allowances for
stockpiling in their calculations mentioning the figure of 70,000 barrels per day in
1978, but there is good reason to doubt even this amount of stockpiling.

One reason for scepticism is simply that the size and ramifications of one-and-a-half
or three years of petroleum storage would go far beyond the probable. At present,
in countries belonging to the International Energy Agency, the target for strategic
stockpiling is 90 days of normal consumption. Most of these countries now have
around that amount, and even this has only been achieved after much pressure
from the International Energy Agency and from strategic hawks in Government,
much to the chagrin of the oil industry. In developing countries which are not
producers of oil, the ratio of storage to consumption is normally higher, but
extremely high rations are only found in countries with pitifully low consumption
levels. South Africa must consume at least 200,000 barrels per day and may
consume as much as 320,000 barrels per day. Even proceeding from the lower
figure, the amount is totally absurd for a country which has never clearly
explained where it is storing its oil and when and how it built the storage
facilities. In addition, there are cost factors which give us grounds for scepticism. At $3.5 per barrel - which is what storage costs in the United States under much more favourable conditions - the cost of these facilities would be around $750 million. The oil itself would cost $1.25 billion, in addition to which there would be an inventory loss. We will further discuss this factor later.

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What little is known about storage in South Africa is that there are exceptionally large storage facilities in the harbour of Durban. However, these are on public view and they have never been a matter of secrecy. Besides they were there long before the question received any particular strategic importance. The rumour-mongering has tended to concentrate on underground storage facilities, no further details being given. Lurid tales of "disused mineshafts" can be summarily dismissed because mineshafts are hardly suitable for storing petroleum. Larger volumes of petroleum are almost always stored in containers with floating roofs, or containers which are round, or egg-shaped or bell-shaped. The reason is that volatile vapours form which must be controlled. A mineshaft with innumerable corridors, cross-shafts, open seams, pockets, etc., would seem to be the worst possible medium for storing petroleum from this point of view. In the United States and in the Federal Republic of Germany underground storage of petroleum is normally done in so-called salt caverns which are semi-natural formations. Geologically speaking, there are fewer of these in South Africa and they are normally not found at higher altitudes where the oil is assumed to be stored since rumours have always suggested the Transvaal. Where naturally formed dome-shaped salt deposits are found, the salt can be removed and the hollowed-out area used for storage, but the estimated United States cost of $3.5 per barrel applies to areas with plenty of geological formations of this type. To hollow out underground areas and then build metal-lined storage tanks would be too expensive for such large-scale strategic stockpiling.

The construction of such underground storage units from salt caverns leaves huge waste heaps which resemble slag heaps. The normal procedure for construction is water-intensive, and water is a scarce resource in South Africa. The same procedure requires the dumping of such huge amounts of brine that the salt level of coastal and riverine waters rises noticeably. None of these things have been observed in South Africa at any time in the last two decades. The construction and maintenance of such storage units would require all sorts of pumping and filtering equipment, but it is possible that they can be provided by experts and companies which supply the mining industry. Construction of such storage units is actually a form of mining. Here South Africa may possess the necessary expertise and may be able to obtain the components domestically. But then there is the question of pipelines. The United States system, for example, involves a complex network of pipelines and has, in fact, been built in the immediate proximity of established pipeline networks. There is no indication that South Africa, which does not produce pipelines on pipeline-related equipment to any extent, has ever been a large customer for this type of thing among foreign suppliers. It can also be pointed out that the extent of reserves which the South
African authorities claim to have would put the number of such underground storage facilities at at least 40. This would not be hidden from the view of reconnaissance satellites. In addition, the aforementioned naval officer who was condemned for passing strategic secrets to a foreign country is assumed to have known about the petroleum stockpiles. All of this underground storage constructions is supposed to have accomplished in the late 1960s and early 1970s, at a time when even the countries members of the International Energy Agency attached little importance to underground storage construction. A review of the technical ramifications of such large-scale stockpiling alone casts considerable doubt on South African claims.

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TABLE SHOWING POSSIBLE LENGTH OF TIME V SOUTH AFRICA COULD WITHSTAND AN OIL CUT-OFF UNDER VARYING LIQUEFACTION, STORAGE AND CONSUMPTION CONDITIONS

<table>
<thead>
<tr>
<th>Sasol output</th>
<th>If stockpiles are:</th>
<th>6</th>
<th>15</th>
<th>6</th>
<th>15</th>
<th>6</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>b/d</td>
<td>months/year/months</td>
<td>320,000 b/d</td>
<td>220</td>
<td>441</td>
<td>551</td>
<td>229</td>
<td>458</td>
</tr>
<tr>
<td></td>
<td></td>
<td>280,000 b/d</td>
<td>227</td>
<td>454</td>
<td>568</td>
<td>238</td>
<td>475</td>
</tr>
<tr>
<td></td>
<td></td>
<td>250,000 b/d</td>
<td>234</td>
<td>468</td>
<td>585</td>
<td>247</td>
<td>493</td>
</tr>
</tbody>
</table>

a/ in number of days.

One remark is appropriate. There is every reason to believe that there are large storage facilities, probably underground, in the immediate vicinity of the plants at Secunda. This applies to much more than oil, for both coal and non-liquid by-products have to have sufficient buffer storage to protect that plant from abrupt disruptions in supply or off-take. This is necessary to ensure against costly and potentially disastrous disruptions of the throughflow. But other than that, we have no idea where South Africa's strategic storage units are to be found. It is logical to assume that they are located near the harbours, the refineries and the Sasol plants. This for purely logistic reasons.

Experts, scorning claims of three years' supply, have been more charitably disposed to accept one-and-a-half years. Bailey and Rivers had calculated that 70,000 barrels per day of oil were being stockpiled over long periods of time and were consequently willing to accept 18 months of storage for operational estimates. There is general agreement that much of this was run down while the South African authorities were adjusting to the cut-off of Iranian oil in 1979. There is also general agreement that the storage facilities were filled up again when the retail price was finally relaxed in 1983. If we assume that they and been successfully stockpiling for five years at a rate of 70,000 barrels per day, stockpiles would have been increasing by 3.5 million tons per year and after five years' time would come to a total of 17.5 million tons. At an assumed consumption level of 280,000 barrels per day, the reserve would last only 15 months. This is as far as we feel anyone should go in allowing for strategic
stockpiling because even this figure has been made possible by excessively generous allowances for South African claims. It is this expert's belief that the figure of 70,000 barrels per day was too high to begin with, that much of those stocks were run down for long periods of time before the situation stabilized, that there is no evidence that South Africa has the capacity to store anywhere near this amount, and, in addition, our own estimates of consumption have been kept as low as possible for reasons of caution.

Let us further clarify what this figure would mean otherwise. The total amount of oil in storage would be 127.5 million barrels and would have a market value of $3.832 million at present price levels. This would then have to be adjusted upwards by an additional $640 million in order to allow for a "pariah penalty" averaging $5 per barrel. The storage facilities alone would have cost $500 million, as a minimum estimate. A further ramification, not immediately obvious to the layman, is that an enormous opportunity loss is being incurred on tied-up inventory. At a reasonable interest rate, say 1.5 per cent over Libor, this opportunity loss would come to $480 million annually at present. We do not particularly believe what the South African authorities claim about their strategic stockpiling, but if what they say be true, then it would mean that they have purchased a relative degree of protection from the oil embargo with a financial bloodletting of appalling dimensions. Judging South Africa's "period of grace", the amount of time it could survive an oil cut-off, would then be accomplished simply by crossing these three variables. This is done in the table on the preceding page. The table is based on our estimates of Sasol's production, net domestic demand, and strategic stockpiling reserves. This is done under certain simplistic assumptions: that no further growth occurs after an effective oil embargo has been imposed, that radical conservation measures are not adopted, etc. In general, however, except for the question of storage, our estimates have been exceedingly cautious. If anything, this table may overstate South Africa's "borrowed time" in case of an effective oil embargo. Furthermore, the table and the calculations in it refer to the amount of time left before the last drop of petrol is used and the entire economy comes to a "grinding halt". It is merely an heuristic fiction. In reality, there is little reason to believe that things would ever get that far. In addition, it is hardly our intention to destroy the South African economy by bringing it to a "grinding halt". The strategy of an effective oil embargo is that, once South Africa is trapped and has no more access to petroleum beyond what it already possesses and can produce, in other words, once its "days are numbered" to something relatively modest, such as 22 months (652 days), its financial collaborators and backers abroad will lose all confidence in its ability to survive and will withdraw further co-operation and financing. It is this, and not the "grinding halt" itself that will be the knell that summons the racist yon.


7/ Petroleum Times, March 1983.

8/ See graph in the Financial Mail, 27 August 1982, conspicuously left without any figures.


1/ Financial Mail, 18 February 1982.


L/ A basic introduction to mining can be found in the Republic of South Africa Official Yearbook 1983, chapter 33; a similarly introductory description at a higher technical level is found in the November 1982 issue of McGraw Hill Inc.'s Engineering and Mining Journal.


L/ South African Digest, 5 February 1982.

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j/ Grainger/Gibson, ibid, p. 223.
-/ Bailey/Rivers, op. cit. 1/ Time, 20 August 1979, p. 42. 47._/ Financial Mail, 8 May 1983, p. 80. L8/ Oil and Gas Journal, 2 May 1983, p. 80. A/ Financial Mail, 10 December 1976, quoted in Bailey/Rivers, op. cit. p. 54, who add that they saw these figures in other publications on frequent occasions around the same time. To convert million tons per year to barrels per day, one normally multiplies by a co-efficient of 0.02, but in the above calculations 0.022 has been used. This is permissible and we use it ourselves because the Sasol plants produce towards the lighter end of the barrel.
5/ Perry Nowacki, Coal Liquefactions Processes, Park Ridge (New Jersey), 1979, p. 163.
5/ In a paper read at the American Petroleum Institute's Refining Department Meeting, Chicago, 11-14 May 1981. 5/ Nowacki, op. cit.
5/ Grainger/Gibson, op. cit#I pp. 222-223. 5/ Lurgi GmbH, company bulletins and publications: Kohle Technologie
0 160e, no date, p. 15 and p. 17; Lurgi Information, July 1981, pp. 6-11; Motor Fuel from Coal, 0 1337/9.79, p. 3 and pp. 9-12.
7Q/ Grainger/Gibson, op. cit. p. 221. 171 Ibid. p. 378.
/ T. van Herwijnen "When is the Liquefaction of Coal Economic?' , Mine and Quarry, September 1980, p. 66.
/ Hydrocarbon Processing, January 1976, p. 11.
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