1.2.2 Liquefaction Programs

Coal liquefaction was demonstrated in Germany at the beginning of this century: Bergius investigated the catalytic process, Pott and Broche the non-catalytic process. Both methods are still the basis of the newly developing hydrogenation processes.[12] Between 1927 and 1945, 12 commercial-scale hydrogenation plants were operated with coal or coal-derived tars as a feed.[13] In 1943, the major part of the German motor fuel consumption of nearly 4 million tons a year was produced by coal liquefaction. After the end of the second world war, coal liquefaction was no longer pursued in Germany for economic reasons.

The basic technological know-how of the old, large projects has been used when the new hydrogenation processes became the basis of the new German technology in the early seventies. Objectives of the current projects are:[12]

- o Reduction of process pressure and hydrogen consumption
- o Increase process efficiency to reduce coal consumption
- o Improve solid-liquid separation by distillation.

Ruhrkohle AG (RAG), Saarbergwerke AG (Saarberg) and Rheinische Braunkohlewerke AG (Rheinbraun), which are major coal mining companies, and Bergbau-Forschung are currently involved in the development of hydrogenation processes. Ruhrkohle AG is providing partial funding for the EDS demonstration plant in the United States and was a partner in the recently cancelled SRC-II project. Steag AG also provided partial funding for the SRC-II plant. A summary of these projects is given in Table 1.4.

In addition to government sponsored programs, Rheinbraun, Udhe, and Mobil Research and Development Corporation have formed a joint venture to develop a fluid bed version of Mobil's catalytic process for converting coal into gasoline via methanol. The first step of the joint venture will be a pilot plant converting up to 1 tonne (1.1 tons) of coal per hour, scheduled to come on stream by April 1982. Future plans include a commercial demonstration involving four or five pressurized fluid bed reactors producing one million tons of high-octane gasoline.

Table 1.4. German coal liquefaction development efforts

Company	Project	Site (district)	Capacity (coal t/d)	Budget ($ million)	Sponsor	Process data	Products	Schedule
rkohle AG (RAG) a Oel AG	Pilot plant	Bottrop (Ruhr)	200	150	State govt. NRW (MWMV)	Catalytic hydrogenation 30 MPa (4350 psi) 475°C (890°F)	Synthetic fuels 30 t/d gasoline 70 t/d middle oil 40 t/d gas	Planning & Const. (P&C): 1977–1982 Operation (O): 2 1982–1984
rberg	Process development unit (PDU)	Reden (Saar)	0.5	4	Federal govt. (BMFT) and state govt. Saar	Catalytic hydrogenation 475°C, 30 MPa (890°F, 4350 psi)	Synthetic fuels chemical feedstock	P&C: 1974–1976 O: 1976–1979
	Pilot plant	Volklingen (Saar)	6	28	Federal govt. (BMFT) and state govt. Saar	Catalytic hydrogenation	Synthetic fuels 0.75 t/hr naphtha 1.80 t/hr middle oil 0.80 t/hr gas	P&C: 1977–1980 O: 1980–1983
gbau-Forschung	PDU	Essen (Ruhr)	0.5	16	State govt. NRW (MWMV)	Catalytic hydrogenation	Synthetic fuels	P&C: 1975–1976 O: 1977–1983
inbraun	PDU	Wesseling (Rhein)	0.25	3	Federal govt. (BMFT)	Hydroliquefaction of brown coal 420°C, 30 MPa (790°F, 4350 psi)	Synthetic fuels	P&C: 1978 O: 1979–1981
f Mineral ources Co. rkohle AG/ ag AG	SRC-II demonstration plant	Morgantown, West Virginia	6000	1270		Solvent extraction 14 MPa (2030 psi) 450–480°C (840–900°F)	Synthetic fuels 1945 t/d fuel oil 440 t/d naphtha 420 t/d gas	1975–1985
on rkohle AG	EDS pilot plant	Baytown, Texas	250	300		Solvent extraction 10–15 MPa (1450–2175 psi) 450°C (840°F)	Synthetic fuels 32 t/d gasoline 17 t/d middle oil 18 t/d heavy oil 17 t/d gas	1974–1982

1.2.2.1 RAG and VEBA Oel AG 200 t/d Pilot Plant[12,UB] In November 1977, the decision was made to construct a 200 t/d plant for catalytic coal hdyrogenation. The plant is under construction in Bottrop close to a coking plant. Gas, water, steam and electricity are suplied by the coking plant and hydrogen is taken from a pipeline passing the site. Waste streams are handled by the coking plant.

The basic engineering was carried out by Ruhrkohle AG and Veba Oel AG. Project management is also performed by both companies.

The site for the pilot plant was officially inaugurated on May 21, 1979, by the Minister of Economics of the State of North Rhine-Westphalia. The plant was completed and start-up operations began in July 1981.

The investment for the 200 t/d pilot plant amounts to $73 million. The operating costs for a three year demonstration period are budgeted at approximately $73 million. Furthermore, there is a six-year budget of $13 million for lab-scale tests underway at Bergbau-Forschung GmbH to characterize the product and improve the process details. The overall expenses of $150 milion are largely sponsored by the Ministry of Economics of the State of North Rhine-Westphalia.

1.2.2.2 Saarberg 6 t/d Pilot Plant[12]. The Saarberg processs for coal liquefaction is also based on the I. G. Farben process of high-pressure catalytic hydrogenation of coal aiming primarily at the production of distillate oils. The process has been proven in numerous bench-scale test runs. At present, Saarberg has a pilot plant with a coal throughput of 6 t/d. Construction was completed in 1980.

The Saarberg plant will include upgrading of the oil products [consisting of one part naphtha/two parts of 200°C (390°F) middle oil] from liquefaction. This work is being done by their BASF partner and includes catalytic gas-phase hydrogenation. Some 100 liters (25 gal) of 100+ octane gasoline has been produced from coal liquids for testing in automobiles. The 6 tonne/day plant was said to produce from 2-3 tonnes (2.2-3.3 tons) of oil products/day.

Operation of the pilot plant was expected to start in September 1980.[14] This project, with a total expenditure of approximately $16 million, is sponsored by the Federal Ministry of Research and Technology and by the Ministry of Economics of the State of Saar.

The design of a 2 x 10^6 tonne/yr (2.2 x 10^6 ton/yr) of coal commercial plant to produce 830,000 tonnes/yr (913,000 tons/yr) of gasoline is in progress. Recent information indicates that this plant is planned for construction during 1983-86 and operation in 1987.[UH]

1.2.2.3 Rheinbraun 0.25 t/d Test Plant

The Rheinbraun direct liquefaction process (or HVB process, from the German Hydrierende Verflussigung von Braunkohle) is based on the work of Bergius and Pier in the 1920's and operation of WW-II production facilities at Wesseling. The key feature of the HVB process is the application of this technology to brown coal (i.e., lignite).

Rheinbraun has operated a test plant with a throughput of 0.25 tonnes (0.3 tons) per day since 1978. The test plant is being used to develop basic data for the construction of an HVB pilot plant which is planned to start operating in 1985. The pilot plant will have a coal throughput of 15 metric tons/hr (16.5 tons/hr) and will constitute the final development step prior to construction of a commercial HVB plant in the Rheinish area.

The first line of the commercial plant, which will serve as a demonstration plant, will have a coal throughput of approximately 250 metric tons (275 tons) of raw coal per hour. Expected to start operation in the early 1990's, the demonstration plant will produce 400,000 metric tons (440,000 tons) of motor fuels and/or chemical feedstocks per year (440,000 tons/yr of motor fuel is equivalent to about 9000 barrels/day).

1.3 Japan

The country is faced with some unfortunate circumstances with regard to its energy position. Its 105 million people consume some 150-155 GJ/person (142-147 million Btu/person) annually giving the nation an overall energy consumption of about 16,000 PJ/year (15 x 10^{15} Btu/yr = 15 quads/yr) in 1976.[15] The major problem facing Japan is not the per capita annual consumption (about the same as the United Kingdom) but the dependence on foreign sources for 88% of its energy supplies.[16]

Indeed, oil imports in 1978 accounted for 72.5% of the country's energy supply. Coal imports were 13.1% and LNG imports were 1.8% of supply. Compared with oil imports, domestic oil production is miniscule. Natural gas production in Japan is about half the rate of LNG imports. However, the country's coal production is about 20 million tonnes (22 million tons) per year which is about a quarter of the demand.[17]

Renewable resources such as hydropower and geothermal power are being used for electricity generation but in 1978 these supplied only 5.0% of the overall energy demand. Nuclear energy is also being used for electricity generation.

When the world oil situation started to deteriorate in 1973, Japan was forced to consider the options that were available. Being so heavily dependent on imported oil (about 75% from the Middle East and 90% from OPEC countries) caused a great deal of attention to be focused on oil use. It was reasoned that the quantity used could not be significantly diminished but the supply base could be diversified. In fact, diversification has become the keystone of Japan's strategy - the more fuel types in the mix, the more countries that would be supplying Japan with energy.

Even synthetic fuels from coal would not lessen the country's dependence on imported fuel supplies, but the coal would come from non-OPEC countries such as Australia.

Japan is also committed to a nuclear power industry including advanced reactor technology such as the liquid metal fast breeder reactor and the CANDU reactor. The target is to have 33,000 MW of generating capacity by 1985 and 60,000 MW by 1990.[17] They are also pursuing research in nuclear fusion.

1.3.1 National Energy Programs - Sunshine Project

Japan's effort to diversify primary energy sources led them to initiation of the Sunshine Project[J1.1] in July 1974, with funding shared by both the government and private enterprises. The major goal of the project is to stabilize future energy supply in Japan through deelopment of innovative technologies to make use of such non-nuclear energy sources as (a) solar energy, (b) geothermal energy, (c) coal-derived liquid and gaseous fuels, and (d) hydrogen energy. Concomitant potential environmental problems are also attacked under the project. The Sunshine project represents a combined effort between the government-owned laboratories and institutes and private R&D supporting enterprises. The total R&D funds required for the project during the 1980-1990 period are estimated at 2.4 trillion yens (about $10 billion) of which two-thirds (1.6 trillion yens) come from the public funds and one-third (8 billion yens) from the private funds. The funds for coal conversion R&D activities account for 70% (1.68 trillion yens) of the total.

1.3.2 Coal Conversion Process Development

The recent status of development of major coal conversion programs under the Sunshine project[J1.1-1.3] is outlined in Tables 1.5 (gasification) and 1.6 (liquefaction). Development of the coal gasification technology in Japan, however, is unrelated to that of liquefaction processes (all direct liquefaction mode). Rather, the development of gasification technology is directed toward production of a low-calorific gas as fuel for power generation in the co-generation system and (b) high-calorific gas as potential fuel for domestic and industrial uses.[J1.2, J1.4]

Table 1.5 Development Status of Major Japanese Coal Gasification Programs (Sunshine Project)

Program Subject	Current Status
High-Calorific Gasification Technology	
(1) Gasification fundamentals	Design and construction of moving-bed gasifier, and measurement of "stickiness" characteristics of coal are in progress.
(2) Characteristics of methane synthesis catalysts	Long-term testing on life-expectancy of sulfur-resistant catalysts is underway.
(3) Gasification characteristics of coal char under high-pressure	Experiments are being carried out with increase in gasifier pressure from 10 atm to 20 atm (∿1-2 MPa).
(4) High-pressure moving-bed gasification of coal/heavy oil hybrid feed	Gasification tests are being conducted at 30 atm (∿3 MPa) to investigate variation in gas composition.
(5) High-pressure moving-bed gasification with steam injection	Gasification process conditions are being evaluated through gasification tests to produce hydrogen-rich water gas.
(6) Development of high-calorific gasification plant	Fabrication of equipment and clearing of land for gasification plant (20 TPD) are in progress.
Low-Calorific Gasification Technology	
R&D activities pertaining to low-calorific gas for power generation	Tests and evaluation continue 5 TPD coal gasification plant; construction of 40 TPD plant was scheduled for completion in FY 1980.
Plasma Gasification Technology	
Fundamental of plasma gasification of coal	Tests based on mixed feed (coal and gaseous hydrocarbon) and determination of temperature profile are in progress.

Table 1.6 Development Status of Major Japanese Coal Liquefaction Programs

Process	Developer	Primary Product	Current Status
	National Project (Sunshine Project)[a]		
(1) Solvolysis	• Natl. Ind. Res. Inst., Kyushu • Mitsubishi Heavy Industries Ltd. • Electric Power Development Co. (EPDC)	Solid (SRC) → Liquid	• PDU (1 TPD) operating • P.P. (40 TPD) in design stage
(2) Solvent Extraction	• Sumitomo Metal Industries Co., Ltd. • Sumitomo Coal Mining Co., Ltd. • EPDC et. al.	Solid (SRC) → Liquid	• PDU (1 TPD) operating
(3) Direct Hydrogenation	• Govt. Ind. Development Lab., Hokkaido • Mitsui Eng. Shipbuilding Co., Ltd. • EPDC et. al.	Liquid	• PDU (2.4 TPD) under construction
	Private Project		
(4) Kominic	• Kobe Steel Ltd. • Mitsubishi Chemical Industries, Ltd. • Nissho Iwai Co., Ltd. et. al.	Solid (SRC) → Liquid	• PDU (0.5 TPD) operating
(5) Mitsui SRC	• Mitsui & Co., Ltd. • Mitsui Mining Co., Ltd. • Mitsui Cokes Co., Ltd.	Solid (SRC)	• PDU (5 TPD) operating
	International Cooperation[b]		
(6) EDS	JAPAN MITI JCLD[c] Exxon	Liquid	• P.P. (250 TPD) operating
(7) SRC-II	JAPAN MITI JCLD PAMCO/Gulf	Liquid	• P.P. (30 TPD) being closed down

[a]Sponsored by Agency of Industrial Science Technology of Ministry of International Trade and Ministry (MITI).

[b]Sponsored by Japanese MITI and JCLD.

[c]JCLD = Japan Coal Liquefaction Development Co.

1.3.3 Industrial Activities and Foreign Cooperative Projects

As indicated in Table J.2, two liquefaction processes (KOMINIC and MITSUI-SRC) are being developed under industrial sponsorship (non-Sunshine Project), while development of two others (EDS and SRC-II) represent the international cooperative efforts with the United States.[18,19] The SRC-II Demonstration project, however, has been cancelled recently.[J1.5] Mitsui SRC, which was a member of the SRC-II consortium, is considering a possible alternative plant that could process about 1000 tonnes/d of coal. Furthermore, a Japanese consortium of 12 companies continues to participate in the Exxon EDS project at Baytown, TX, with a contribution of about 8.3% toward the total fund.[19,1.5]

Another cooperative project between the Japanese and U.S. companies has been initiated recently by Nippon Oil Ltd. and Chevron Research Company.[J1.6] The project is concerned with construction and operation of a pilot plant in Yokohama, Japan, which will use Chevron's propeitary catalytic liquefaction technology to process Australian brown coal. A Japanese joint-venture company (Nippon Brown Coal Liquefaction Company) consisting of five companies - Kobe Steel Corp., Mitsubishi Chemical Industries, Nissho-Iwai Corp., Idemitsu Kozan and Asia Oil - is also involved in a Japan-Australia joint undertaking in the Australian brown coal liquefaction project.[J1.7, J1.8] The initial phase of the project calls for construction of a 50-tonne/d (dry coal) pilot plant near the coal mine in Victoria, Australia, with stage 1 coming on-stream in 1983 and stage 2 in 1985. The plant is based on a catalyst solvent refined process to produce 30 tonnes/d of SRC, 5 tonnes/d of naphtha and 0.3 tonnes/d of sulfur in stage 1, and primarily 17.5 tonnes/d of mid- and heavy-distillate, and 7.5 tonnes/d naphtha in stage 2. The second phase of the project involves construction of a 5000 tonne/d demonstration plant to be completed by 1985. The demonstration plant will serve as the first unit of a six-unit 30,000 tonne/d commercial plant to be constructed by 1990 as the third phase of the project. Separately, Mitsui Coal Liquefaction Company, under an agreement with the Victoria Brown Coal Committee, is performing a two-year feasibility study on a 6000 tonne/d brown coal liquefaction project.[J1.9] Mitsui is also interested in producing metallurgical grade SRC from Victorian brown coals.[4]

1.4 New Zealand

This is a comparatively small county with a land area of 270,000 km^2 (104,000 sq mi) and a population of 3 million.[20] Most of the land area is in the two major islands - North Island and South Island - and the majority of the population inhabits North Island. The people are relatively affluent (on a world scale) and mobile. The automobile population is about 1.25 million[21] and has changed rapidly in recent years to vehicles of smaller engine displacement. In 1973, cars with engines larger than 2500 cc (150 cu in) constituted nearly 40% of the mix and by 1979 they were down to 10%.[21]

New Zealand's energy resources and present production are presented in Table 1.7.[21,22] Coal is the most plentiful resource and is found on both islands. Bituminous coal is found on South Island, subbituminous coal is found on both islands, and lignite, which has the highest indicated reserve, is confined to South Island. The oil that is found is condensate associated with the natural gas. Major finds of natural gas are comparatively recent (1959, 1969) and the gas fields are on or lie offshore the west coast of North Island (the Taranaki district). As far as renewable resources are concerned, geothermal wells are found on the central part of North Island while most of the hydroelectricity is generated on South Island.

Table 1.7 New Zealand energy resources, production and consumption (Petajoules)*

	Known reserves					
	Proven/ measured	Probable/ indicated	Possible/ inferred	Total resource	Production 1978	Consumption 1978
Non-renewable						
Coal	5,000	47,000	14,000	66,700**	49.5	49.0
Oil	150	1,195		1,345	25.6	192.0
Gas	980	4,960		5,940	59.5	59.0
Total	6,270	52,360	14,000	73,290	134.7	300.0
Renewable (Annual Supply)						
Hydro	86	123		209	55.8	60.0
Geothermal	12	13	15	40	4.3	
Total	98	136	15	249	60.1	60.0

*Petajoule = 10^{15} joules = 0.9478 x 10^{12} Btu.

**Source: Ministry of Energy

The government of New Zealand through the Ministry of Energy has adopted five energy strategy goals.[21] These are:

1. To reduce New Zealand's dependence on imported oil. The present degree of dependence on imported oil is considered undesirable.

2. To increase diversity in New Zealand's energy supply system. Reliability of energy supply will be a key element in New Zealand's future development while dependence on a single source is to be avoided. They are trying to use energy sources that match the quality needed. They are also attempting to be prepared to develop a particular energy type if it is needed. An attempt is being made to reduce the transport of energy by using the fuel near the source.

3. To ensure that energy is used efficiently through the reduction of waste and by using appropriate energy types. Government actions are directed towards reducing wasteful consumption of energy, making existing capital equipment more energy efficient by modification or replacement, encouraging improvements in energy standards for new capital investments and stimulating awareness of opportunities for saving energy among all New Zealanders.

4. To transfer energy supplies from non-renewable to renewable sources in the long term. A smooth transition is required from the present heavy dependence on oil- and gas-derived fuels to those derived from biomass and other renewable sources.

5. To encourage a framework for energy planning which provides for changing social and economic circumstances. They have recognized that the social and economic goals of the people will have to be compatible with the energy sources that are at the country's disposal.

The central government has a high degree of control over the energy industry in New Zealand. It is directly involved in the production and distribution of electricity, coal and natural gas and in areas where its control is not direct it may regulate through measures such as tariffs, taxes and licensing.[23]

The discovery of the Maui gas field 40 km (25 mi) off the Taranaki coast in March 1969 gave New Zealand a large degree of flexibility in its future energy planning. Reserves in the Maui field are estimated at 5440 PJ (5.2×10^{15} Btu = 5.2 quads) of gas and 1195 PJ (1.1×10^{15} Btu = 1.1 quads) of condensate.[21] Those in the onshore Kapuni field are 500 PJ (0.5×10^{15} Btu = 0.5 quad) of gas and 150 PJ (0.14×10^{15} Btu = 0.14 quad) of condensate. These estimated reserves of 1345 PJ (1.2×10^{15} Btu = 1.2 quads) of condensate from the two fields represent less than a seven-year supply at the present total annual consumption of oil. At present rates of use (about 60 PJ/year) (57×10^{12} Btu/yr) the natural gas would last for about 100 years, but every intention is to use the gas from the Maui field at the rate of 160-170 PJ/year ($150\text{-}160 \times 10^{12}$ Btu/yr) from the mid-1980's to the end of the century and beyond.

Present plans call for maintaining one production well in the Maui field. For the next few years the gas production will be brought up to the desired level of off-take by using gas for electricity generation at the 1000 MW Huntly power plant on North Island. As the planned synthetic fuel facilities come on line, the gas will be diverted to those and the power plant will convert back to sub-bituminous coal.[22]

The scenario for synthetic fuels facilities development had to take into account the role that the Marsden Point (Whangerai, North Island) crude oil refinery would play. It is the country's only refinery and has limited size and conversion capacity.[21] As a result, approximately 35% of total oil imports in 1979 was in final form.

The proposed expansion of the refinery, which was authorized by the New Zealand government in May 1979, had the choice of using fluid catalytic crackers (FCC) or hydrocrackers (HDC) to give the needed conversion capability. A choice of Fischer-Tropsch technology for the synfuels facility would, because of its coproduction of diesel fuel, allow the less expensive FCC units to be used. However, the choice of the methanol-Mobil M-gasoline route[24] has dictated the use of HDC units which produce more diesel and kerosene. The refinery expansion was also to make provision for M15 gasoline (15% methanol) blending.

Petrocorp, New Zealand's state-owned oil company, chose the Mobil technology over the Sasol-type Fischer-Tropsch process in November 1976,[25] and on April 1, 1980 signed an agreement with Mobil Corporation.[24] For some $500 million, Mobil will build a synthetic fuels plant that is expected to produce 530,000 tonnes/year (583,000 tons/yr = 4.5 million barrels/yr) of motor gasoline. This is approximately one-third of the country's current requirements. The contract provides for the development of a gas-to-methanol converter and a methanol-to-gasoline catalytic unit. The government will have a 75% shareholding and Mobil will have the remaining 25%. Together with the Marsden Point hydrocracker these facilities are expected to let New Zealand become 50% self-sufficient in transportation fuels by the mid-1980's.

Separately, Petrocorp has entered into an agreement with Alberta Gas Chemical Ltd. (AGC) of Edmonton, Alberta for the construction of a stand-alone methanol facility.[26] This will also use Maui field gas as a feed stock to produce about 1200 tonnes/day (1320 tons/day) of methanol. It will be located at Tikorangi on the west coast of North Island near the Maui offshore gas field and will cost an estimated $130 million. Almost all of the methanol is earmarked for export and the plant is expected to be producing by late 1982. AGC will own 49% of the company which will be established to operate the plant. This will allow advantage to be taken of AGC's experience in marketing methanol to the countries on the Pacific rim, such as Japan, Australia and those in Southeast Asia.

Other methods considered for reducing the dependence on imported raw materials are the use of liquefied petroleum gas (LPG) and compressed natural gas (CNG) as automotive fuels. It has been estimated by the New Zealand Liquid Fuels Trust Board that pursuit of this option can substitute 11 PJ/year (10.4 x 10^{12} Btu/yr) or 231,000 tonnes (254,000 tons = 2 million barrels) of gasoline by 1985.[21] Some thought has also been given to selling a 15% methanol-85% gasoline (M15) blend instead of straight gasoline. The Liquid Fuels Trust Board is still conducting trials and a decision has not yet been made on the adoption of M15.

At the present time coal plays a very small role in providing synthetic fuel energy. Manufactured gas, which is confined mainly to South Island, is declining in use. Made from coal or imported naphtha, it supplies only 1 PJ/year (0.95 x 10^{12} Btu/yr) of energy. Most of the existing gas production plants are expected to close down over the next few years as a result of the phasing out of government subsidies from April 1980 and the competition from natural gas based fuels.

In the long run, New Zealand's large coal reserves (especially lignite) will probably be used to produce synthetic liquid fuels to replace the dwindling supply from the Maui gas field. One conflict exists with the lignite and that concerns its location near the surface but under some of South Island's prime farm land.

1.5 South Africa

This is a country with bountiful mineral resources with one conspicuous exception - petroleum. Because of its original complete dependence on foreign sources for raw materials to supply the country's liquid fuel needs, South Africa has done much to minimize its use of liquid fuels and to develop alternative sources for such liquid fuels.

Coal is the country's most abundant energy resource with extractable reserves estimated at 61 billion tonnes(67 billion tons).[27,UW] The present (1979) extraction rate is over 100 million tonnes (110 million tons) per year but this is expected to increase substantially to meet the demands of the Sasol Two and Three synthetic fuels facilities [combined requirement of 27 million tonnes (30 million tons) per year], increased exports to Japan and Europe, and requirements of the additional coal-fired electricity generating capacity being installed by the Electricity Supply Commission (Escom). Nevertheless, the coal reserves will continue to supply the country for at least 200 years. Fig. 1.4 shows the coal fields and refineries in South Africa.

Some anthracite is mined in the northern section of the province of Natal but most of the coal is bituminous and of varying quality. Most of the coal mining activity is in southern and eastern Transvaal region, northern Natal and the northern Orange Free State. Large reserves of coal also exist in the central (Springbok Flats) and northwestern (Ellisras) Transvaal. Both underground and surface mining are practiced. Coal of appropriate seam thickness and ash content below 35% is considered minable to depths of 300 m (980 ft).[27] In underground mining room and pillar, continuous mining and long wall methods are used.

At present South Africa supplies between 75 and 80% of its energy requirements from coal. An increasing amount of chemical feedstocks are also being derived from coal.

Escom, the national electric utility, had an installed generating capacity of 14,400 MW in 1979[28] with two of the six 500 MW generating sets of the Kriel power plant commissioned. During 1979 the utility consumed 43 million tonnes (47 million tons) of coal.[29] Escom has embarked on a $14.5 billion plan to double its generating capacity by 1990.[30] Included in the plan are three more coal-fired power plants (typical size 3600 MW) and a hydroelectric plant. There are already two hydroelectric plants for peak loads. These are at dams on the Orange River and can generate up to 540 MW. A 1000 MW pumped storage scheme is being constructed on the Tugela river in Natal.

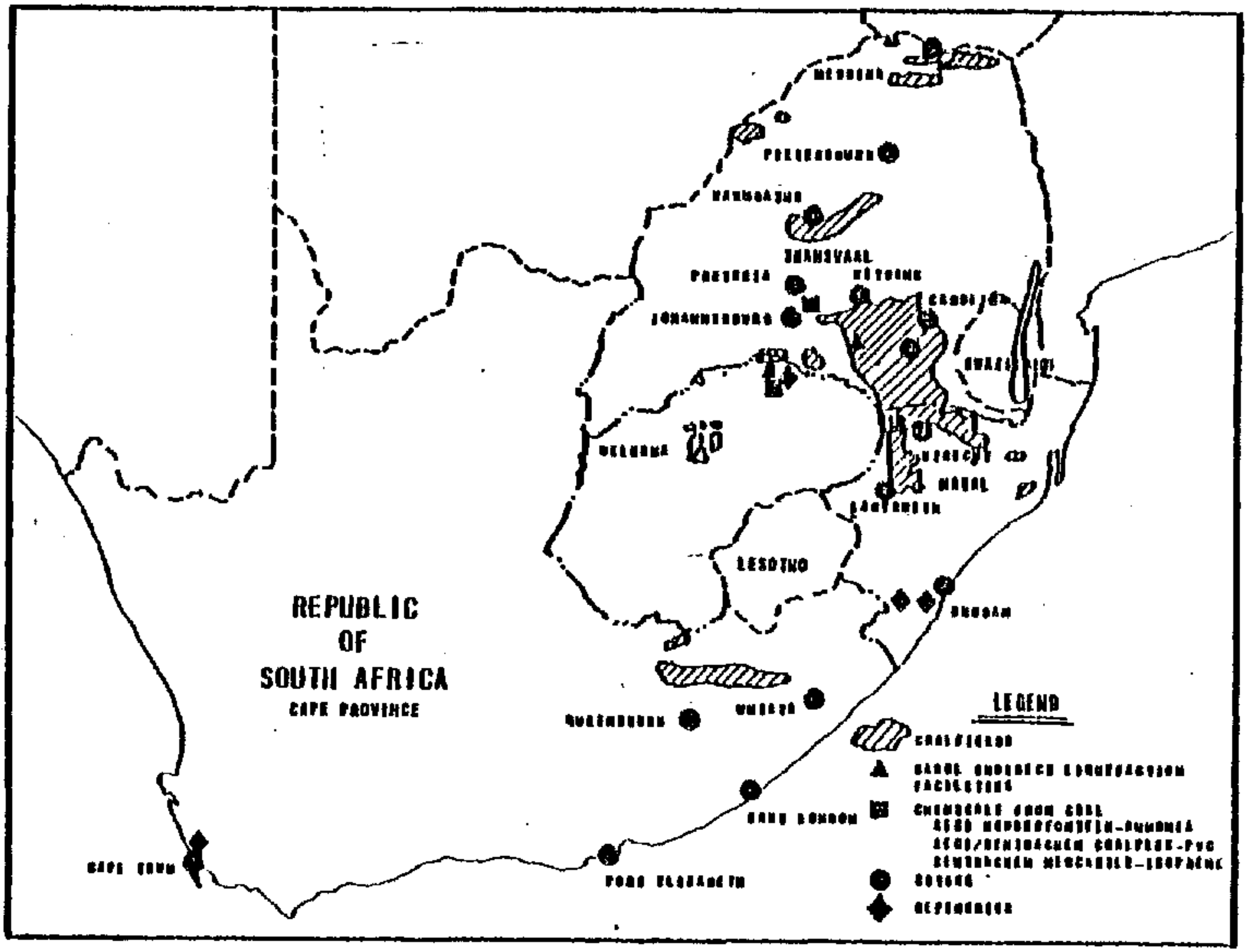

Figure 1.4

COAL FIELDS AND REF. :RIES IN SOUTH AFRICA

Additional hydroelectric power is imported from the Cabora Bassa dam in neighboring Mozambique. With few major rivers, South Africa's potential for hydropower is limited.

A nuclear energy program has been embarked upon by Escom. The two-unit 2000 MW Koeberg power plant on the Atlantic coast north of Cape Town will be the first phase and will come on line in 1982.[31] Other coastal stations remote from the coal fields are planned.

Uranium for nuclear fuel is mined locally. Some 5540 tonnes (6100 tons) of uranium oxide were produced in 1979.[32] Most uranium is a byproduct of the gold mining operations. However, some uranium deposits are away from the gold fields[33] and some is present in coal ash. Because the United States refused to supply enriched uranium for the Koeberg reactors, the Uranium Enrichment Corporation (Ucor) developed its own enrichment process and has a pilot plant in place at Valindaba near Pretoria.[31]

Oil and natural gas exploration is conducted by the Southern Oil Exploration Corporation (Soekor) in which Sasol has a 50% share. Various rigs have drilled offshore in Algoa Bay and Mossel Bay regions of the south coast and the Orange River mouth on the west coast. So far no economically viable deposits have been found. The biggest strike was natural gas in the Mossel Bay region but it was too far from the potential consumers to develop. The on-shore drilling program has not yielded any oil or gas.

Prior to the last quarter of 1973, crude oil had been freely available to South Africa. Four refineries processed the crude into transportation fuels. They were the Caltex (California Standard and Texaco) refinery in Cape Town, the Mobil and Sapref (Shell and BP) refineries in Durban and the Natref (Sasol, Total and the National Iranian Oil Company) refinery in Sasolburg. This last had some unique features. As an inland refinery (350 miles from the coast) all the black oil fractions have to be hydrocracked to lighter fractions in order to be sold. Some transportation fuels were imported from the Sonarep refinery in Maputo, Mozambique.

Since 1973 the Arab nations have refused to supply South Africa with any crude oil. This made the country very dependent on Iranian crude oil supplies. These, in turn, were cut off in 1979. These events brought about serious consideration and implementation of greater use of country's coal reserves by expanding the synthetic fuels industry.

Conservation measures are directed very heavily towards saving transportation fuels. The price of the gasoline, diesel and other fuels has been allowed to rise very steeply. The present (last quarter of 1980) price of gasoline, at about $2.80/U.S. gallon, is more than five times what is was in 1971. About $0.20 of this is a levy that is helping to finance the Sasol Two and Three synfuels facilities. A second conservation method was the restricted business hours for retail gasoline and diesel outlets. Service stations are not allowed to sell fuel at night or during weekends. Speed limits were reduced on all highways and the present national speed limit is 90 km/h (56 mph) with heavy fines and automatic jail sentences for offenders caught and convicted of exceeding 125 km/h (78 mph).

Because it is a country that is more than able to feed itself, South Africa could easily divert some of its agricultural production into the manufacture of fuels. Schemes to produce ethanol from corn and sugar cane have been proposed. In the Johannesburg (Witwatersrand) region of the country, where half of the people live, gasoline is already being extended by 10% ethanol addition. Although this ethanol is from coal, the use of ethanol from other sources is quite feasible. Another proposal that is being field tested is the use of sunflower seed oil in diesel engines either as a diesel extender or by itself.[34] Some success has been achieved.

Some parts of the country, notably the Karoo semi-desert and the Kalahari desert regions, are especially suited to solar energy applications. They receive a great deal of sunshine and are remote from the more common energy supplies.

The production of synthetic fuels and chemical feedstocks from coal has been established in South Africa for a long time. The first government attention was a White Paper published in 1927 on the production of liquid fuels from coal. The Sasol One facility went on line in 1955 and is still producing a variety of fuels and chemical feedstocks. The 1973 oil embargo led to the government's December 1974 decision to construct Sasol Two at Secunda. This facility was completed in late 1980 and was operating at about 70% of its design production rate in March 1981.[UBB]

The change in the Iranian government led to the February 1979 decision to build Sasol Three next door to Sasol Two. In September 1980 it was already 30% complete[35] and expected to be in production by the end of 1982.

The status (as of March 1981) of Sasol II and III is presented in Table 1.8 along with estimates of the potential and published yields of motor fuels from these plants. The initial published yields are given as 35,000 barrels per day but these were increased later to about 40,000 barrels per day which is not consistent with the official South African announcement that Sasol II and III would produce 47% of the motor fuels currently consumed in that country. In addition, the actual capacity of the Lurgi gasifiers is probably at least 25% greater than the design capacity so that the plant is probably capable of achieving at least 60,000 barrels per day of motor fuel at increased throughput (and coal feed) rates. Planning is in progress for installation of Sasol IV ( ) within the next decade. It will probably be located at Sasolburg, the site of Sasol-I rather than at Secunda, which is the site for Sasol II and III.

Besides displacing crude oil used to manufacture transportation fuels, chemicals from the Sasol II/III complex will dispalce naphtha-derived ethylene as a feedstock for polyethylene and polyvinyl chloride production, and provide alcohols and ketones for a wide range of products.

South Africa is also increasing its efforts in marketing Sasol technology in other countries. Projects in the U.S. and Australia, for example, have been mentioned.

Table 1.8. Status of Sasol II and III.

I. Status of Operations (March 1981)

Sasol II	Operating at 70% of capacity
Sasol III	Construction about 50% complete
Sasol IV	In planning stage

II. Motor Fuel Yields for Sasol II

Source	Gasifier coal 10^6 tonne/yr	Motor fuel yield bbl/D
Sasol ( )	8.4	35,000
C&E News ( )	8.4	40,000
Financial Times ( )	-	59,000[a]
Lurgi ( )	8.8	50,000
	(8.4)	(47,700)

[a]Indicates that Sasol II and II will produce 47% of South African motor fuel consumption (estimated at 250,000 bbl/d in 1980). Therefore, Sasol II should produce about 59,000 bbl/d assuming that Sasol II and III have the same capacity.

For a more detailed description of the Sasol Facilities, see the first report in this series by T. D. Pay, *Foreign Coal Liquefaction Technology Survey and Assessment Sasol - The Commercial Experience*, ORNL/Sub-79/13837/4, November 1980.

Coal is also being used by AECI Ltd. as a feedstock for ammonia production. Six Koppers-Totzek gasifiers are used to produce the synthesis gas for a 1000 tonne (1100 ton) per day ammonia synthesis plant.[36] Some of synthesis gas is fed to an ICI methanol unit that produces sufficient methanol to meet all South Africa's requirements.[37]

Some 60,000 tonnes (66,000 tons) of ammonia per year[38] is also produced at Sasol One with some 120,000 tonnes (132,000 tons) per year to be produced as by-product from Sasol Two.[39] As Sasol Three is a copy of Sasol Two it is assumed that another 120,000 tonnes (132,000 tons) of ammonia per year will be produced there.

Another use for coal was established when AECI and Sentrachem built their Coalplex joint venture at Sasolburg. It was commissioned in 1977 and manufactures polyvinyl chloride (PVC), caustic soda and chlorine from coal, lime and salt. PVC production is 100,000 tonnes (110,000 tons) per year.[40]

Two large, semi-closed electric arc furnaces react anthracite and burnt lime together at 2000°C (3600°F) to produce molten calcium carbide at the rate of 147,000 tonnes (162,000 tons) per year. To do this 90,000 tonnes (99,000 tons) per year of anthracite and 143,000 tonnes (157,000 tons) per year of lime are consumed. After solidification, the carbide is crushed to a fine powder and reacted with water in two generators to produce 44,700 tonnes (49,000 tons) per year of acetylene and 160,000 tonnes (176,000 tons) per year of hydrated lime. The latter is sold in briquette form to the cement industry. Diaphragm cells are used to produce the required 90,000 tonnes (99,000 tons) per year of chlorine. Salt, at the rate of 160,000 tonnes (176,000 tons) per year, is used and 230,000 tonnes (253,000 tons) per year of caustic soda is also produced. Nominal production of the vinyl chloride monomer plant is 104,000 tonnes (114,000 tons) per year with 4800 tonnes (5,300 tons) per year of hydrochloric acid by-product. PVC is produced by batch reaction using some 12 autoclaves.[40]

AECI also has an older PVC facility at Umbogintwini near Durban that is a coal-based plant. This plant started operation in 1955 and is still producing PVC.[40]

The Sentrachem group is putting up a coal-based synthetic rubber complex at Newcastle in the heart of northern Natal's coal region. Calcium carbide will be used to make acetylene which in turn will go into isoprene. Acetone, which is the other raw material, will be supplied by Sasols Two and Three.[41]

With government clarification in early 1980 of its position on synthetic fuels made by companies other than Sasol, there has been much private sector interest. General Mining, which owns vast coal reserves on the Springbok Flats in the central Transvaal, has announced that they and Sentrachem are to build an oil-from-coal plant to use this coal if studies show economic viability. So far, drilling to define the coal reserves and pilot plant testing of the coal have been carried out. No plant capacity has been indicated but direct liquefaction with a 30% gasoline and 70% diesel product breakdown is being investigated.[42,43] This is a desirable product mix in the South African context. Another attractive feature of the project is the recovery of uranium, alumina, potassium, and small quantities of molybdenum from the mineral matter.[44] At the moment, South Africa is dependent on imports for alumina and potassium.

In the meantime, Sasol continues to study direct liquefaction at their 0.5 tonne (0.6 ton) per day direct liquefaction pilot plant at the Sasol One facility. It has been in operation since 1971[45] and the process is similar to that used in the SRC-I process.[46] This pilot plant has been leased by the Japanese Kominic Group (See Section 1.1) to produce a coking additive from Victorian (Australia) brown coal.[46] Sasol's main interest lies in the potential of the process for producing transportation fuel.

It is anticipated that with increased coal and uranium exports and decreased crude oil imports, South Africa will soon be a net exporter of energy.