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1974 (April)

POWELL DUFFRYN TECHNICAL SERVICES LIMITED

DRAFT

"COAL (STATE OF THE ART)"

April, 1974

DRAFT
S.C. Brealey/M.S.
19th April, 1974

C O A L

(State of the Art)

(metric tons throughout, unless otherwise stated)

I SUMMARY AND CONCLUSIONS

RESOURCES, PRODUCTION, CONSUMPTION AND TRADE

Coal resources are vastly greater than hydrocarbon resources and widely distributed, but the wide range of qualities and production costs and accessibility present problems in exploitation. World production in 1972 amounted to 2,297 million tons of standard coal equivalent, i.e. 35% of total primary energy. In recent years coal consumption has been falling slowly and its share in total energy more quickly, particularly in the older mining areas of Europe and also Japan. Consumption has more or less been matched by production in most regions with the exception of coking coal which is internationally traded (about 100 million tons per annum), the main importing areas being Europe and Japan and the main exporting areas U.S.A., Canada, Australia and Poland. The oil crisis has resulted in thermal coal (i.e. non-coking coal) entering the energy market on an international scale, although the amounts traded will be small at first. In due course, long-term contracts for coal supplies and for shipping can be expected to multiply as purchasers will wish to secure their sources and avoid the fluctuations customary in the spot markets both for minerals and for shipping.

The developing countries have generally not exploited their coal resources very extensively but there is an urgent need for them to do so in order to mitigate the drain on their foreign exchange, due to the high cost of imported oil and also improve their security of supply and contain inflation. Those favourably endowed should be able to take advantage of export opportunities and thereby further improve their financial position.

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MAJOR USES OF COAL AND PRICES

In the past coal was the main source of energy and carbon for domestic use, industry, gas, and transportation and later for electricity generation and chemicals but at present its main uses are for electricity generation in coalfield power stations and the metallurgical industries and oil has deeply penetrated these areas too. Some heavy chemical production, cement and lime-making installations still use coal but domestic, industrial, gas, and transportation uses have declined rapidly in most countries in the face of oil costing around $2 per barrel and natural gas, and the newer "petrochemical" industry was founded on cheap oil feedstocks and natural gas. In effect the four-fold increase in oil prices has restored coal to its former competitive position although it is unlikely to re-enter directly into transportation. There are many coal deposits which can now be mined and delivered at competitive cost which formerly could only be exploited by subsidising.

Production costs range from around $1 per ton for large-scale opencast lignite mines to around $25 per ton for deep underground mines and it is therefore evident that the economics of exploitation can only be considered in relation to a particular area or even a particular mine, taking into account transportation to the point of use and in comparison with oil delivered to the same point of use - in most parts of the world outside North America, from O.P.E.C. suppliers. In the absence of deliberate subsidies the lowest feasible selling price would be the production cost with sufficient margin to allow an adequate return on investment and the highest feasible selling price would be that of alternative and secure supplies of energy delivered to the point of use. The actual price fixed between these limits will depend on policy and marketing expertise and will tend to the lowest for internal markets and the highest for external markets. However, there will be a period

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of some years for adjustment and during this period we are of the opinion that prices in real terms will rise by about 15% per annum in internal markets in Western Europe and Japan and less than this elsewhere.

The price fixed in export markets for thermal coal is expected to rise rapidly to the opportunity value. We would expect therefore that coal is now competitive in most areas where insufficient indigenous resources of oil exist and where transport is not a problem. This seems particularly true for uses such as power generation, cement manufacture, etc. where a wide range of low-grade coals can be used.

PROSPECTS FOR INCREASING SUPPLIES

Few mines were operating at 100% capacity when the oil crisis began and it can therefore be expected that an increase in production of some 10% could be achieved in a relatively short time. In some areas this will depend on recruiting more labour which recent wage increases will facilitate.

The development of new mines will take longer, particularly if the coalfields are not well explored. Many small operations can be started on outcrops without much know-how or equipment but the larger opencast and underground mines depend on detailed planning and considerable investment in sophisticated equipment. This is the major constraint on expansion and it is a fallacy to believe that it can be overcome merely by increasing the amount of money available. "Planning" in this context is taken to include the process of obtaining all the statutory and legal agreements and satisfying requirements for environmental protection. The minimum period involved for a medium-sized opencast mine would be 2 years for planning and 2 years for development

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and these periods could easily be doubled for a large deep opencast operation or a deep underground mine. It is felt that an overall increase of production of about 7% per annum is the maximum likely to be achieved on a world-wide basis. Where conditions are favourable and resolute action taken this rate could be doubled, but in the declining deep-mining areas it will be very difficult to achieve within a decade (remembering that it may well take 8 to 10 years to bring a new deep mine to full production).

Economics and lead-time considerations will of course favour opencast mining and the proportion of coal won by these methods will increase substantially. Environmental constraints will impede progress in industrial countries and therefore stimulate activity in developing countries.

Prospects for expansion seem to be best in U.S.A., Canada, South Africa, Australia, Colombia, Botswana, and Indonesia in the western world and U.S.S.R., China and Poland in the Centrally Planned Economies. Most of these new mines will be opencast, over the whole range of sizes, followed by drift or adit mines of medium size. Deep mining operations will only expand, and more slowly, in the traditional areas. All the developing countries should expand output from small opencast operations whilst larger-scale operations are being planned. This policy would give immediate relief and provide an opportunity to gain experience.

As regards available technology there seems to be no breakthrough in sight in either opencast or underground operations. Machines will continue to increase in size and output capacity but not rapidly as the law of diminishing returns is now having a serious effect. More attention is being paid to increasing machine "availability" for work by better design, operation, maintenance, etc. In the developing countries the degree of mechanisation to be adopted is frequently controversial but the small outcrop operation mentioned above provides job opportunities. Tight control of these operations is however necessary in order to avoid derilection and improve safety and working conditions.

COAL AS A RAW MATERIAL

The production of low-btu gas, high-btu gas, liquid fuels and chemical feedstocks from coal and lignite has long been established and in operation on a commercial scale, new research being aimed at improving the economics of the processes and also the scale. Widespread claims are made that already the products are competitive in price with those based on oil at present prices. Examples of reported production costs are as follows:-

High-btu SNG (1,000 btu/ft^3)	\$0.60 to \$1.30 per 1,000 ft^3
Liquid products	\$3.80 to \$4.50 per barrel
Motor spirit	\$18 to \$19 per barrel

Even allowing a high degree of scepticism in respect of these figures there is little doubt that some of these processes will be technically and economically viable. The time schedule is less favourable since large plants will be necessary and the lead-time therefore considerable. A decade will be required before any significant impact will be made on the energy scene as a whole. Also it can confidently be predicted that teething troubles will be severe (as occurred with the SASOL plants in South Africa). The best coals for this purpose are high-volatile bituminous coals and lignite with low ash content and particularly low sulphur.

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In the developing countries it seems that a good case could be made for developing relatively small-scale plants which would produce sufficient light oil for internal use by coal distillation, utilising the residual solids and low-btu gas directly for power generation.

FUTURE OF COAL CONSUMPTION

On a world basis consumption of coal seems likely to increase at an average rate of 7% per annum giving the following consumption in 1980 and 1990:-

1972	-	2,297 million tons standard coal equivalent
1980	-	3,950 million tons standard coal equivalent
1990	-	7,800 million tons standard coal equivalent

After 1990 the impact of nuclear power will increasingly be felt and consumption of coal for electric power will therefore fall off until eventually only metallurgical and chemical uses remain.

OUTLOOK FOR PRIVATE INVESTMENT AND BANK INVOLVEMENT

The outlook for private investment in coal development in the developing countries is promising where the political climate permits it because they are in desperate need of the finance and expertise which it would bring in. These projects are likely to be large open-cast mines or smaller drift mines. Small-scale mines naturally fall to local investment. Private investors must however expect to be involved in partnership arrangements etc., where it can be shown that considerable benefits accrue to the host country.

The areas of Bank involvement in the developing countries might include the following:-

(i) Assisting in formulating a coal development policy, review of resources, identification of projects, organisation of mines and geological departments, licensing policies.

(ii) Exploration - provision of experts, aerial surveys, laboratories, studies.

(iii) Marketing - internal and external market studies, pricing policy, competition.

(iv) Transport - internal and external.

(v) Codes of practice - environmental, health and safety, labour, with particular consideration for small mine operators.

(vi) Mine planning - feasibility studies, investigation and testing, mine design.

(vii) Project implementation - finance, purchasing, management, supervision and monitoring.

(viii) Infrastructure - roads, railways, pipelines, ports, power supplies, water supplies, townships.

(ix) Education and training - technologists, technicians, craftsmen, miners, overseas experience.

(x) Processing - development of synthetic liquid fuel plants and power generation complexes on the appropriate scale, coal preparation for premium markets.

II INTRODUCTION

The object of this paper is to review the position as it stands today of the world coal industry, giving the necessary background data so that the significance of the industry in the present and future energy situation can be readily understood by non-specialists. In order to do this comprehensively it is necessary to review coal resources, production, consumption, processing, transportation, and socio-political factors. Annex 1 describes coal as a substance and its mode of occurrence. Annex 2 details the main uses of coal.

COAL INDUSTRIES OF THE WORLD

Coal has, of course, been used as a fuel for many centuries but it was the expansion of iron-making and the demands for steam power which resulted in a rapid expansion of coal mining in 18th-century Europe and this soon spread to the U.S.A. and rather more slowly to other parts of the world.

Oil began to replace coal in transportation in the early 20th century and then later in electric power generation and by 1958 was the predominant fuel as regards convenience and, in most cases, price. The coal industries of Europe and Japan were rapidly run down and coal was reduced in the main to the roles of coalfield power generation and coke production. In other parts of the world, notably the U.S.A. and the Centrally Planned Economies, coal held its own much better although its share of the energy market declined considerably.

The present situation is that, because of the oil policies of the Arab states, coal has become economic again and a scramble has begun to obtain it not only to secure energy supplies but also to mitigate the economic effect of the higher cost of oil. Those industrial and developing countries which exploited low-cost oil supplies to the greatest extent are now in the most difficult position in respect of their future supplies of energy and its cost. Ultimately nuclear power should take over as the main source of primary energy but this will not happen for some decades.

III WORLD COAL RESOURCES

"Coal resources" is understood to mean geological occurrences of coal and carries no implication of extraction possibilities or intention. "Reserves" on the other hand is understood to imply that work has been done on the resources with a view to exploitation. Furthermore constraints in respect of seam thickness and depth are applied to classified reserves. The U.N. definitions which are used as far as possible in this paper are as follows:-

	Coal	Lignite
Minimum seam thickness	30 cm	30 cm
Maximum depth	1,200 m	500 m

Other authorities use different definitions, for instance, a minimum seam thickness of 1 m.

There is no international standard of classification of reserves but all the classifications used indicate the degree of confidence, ranging from "proved" or "measured", through "probable" or "indicated", to "possible" or "inferred reserves in descending order of confidence. Other descriptions are "total" reserves, which is the aggregate of the above categories, "in situ" reserves which is a geological definition, "workable" reserves or "economically recoverable" reserves which are weighted views of the coal which could actually be mined by known methods and within existing economic limits.

The estimates of global resources which exist are therefore subject to considerable uncertainty, the fundamental reason for this being that all estimates give figures which are so large in relation to production that no special effort has been made either to improve their accuracy by exploration or to adopt more accurate estimating methods. In contrast, estimates of oil resources have been more accurate because of the concern for supplies within the next two decades.

Most estimates of reserves only distinguish between hard coal and lignite (anthracite amounting to only some 5% of hard coal). The following table gives the geographical distribution of world coal reserves in the classified categories and from these figures it can be seen that the main reserves of hard coal are in U.S.S.R., China, U.S.A., India, South Africa, Germany, Canada and Poland and of lignite in U.S.A., U.S.S.R., China, Australia and Germany. However, substantial resources exist in many countries and these have not yet been depleted to any significant extent.

The coal resources of Europe have probably been the most thoroughly explored with the highest degree of proof, followed by the U.S.A. and U.S.S.R. In these countries the lower category reserves are so vast that there has been little incentive to explore and thereby improve the classification. In countries which are in a lower stage of development, coal measures have been developed as the necessity arose, (e.g. for railways) and extensive exploration has not been necessary.

The lignite resources are characterised by thick seams (3 to 50 m) near the surface and a high proportion is amenable to opencast or strip-mining. The economics of mining depend on the quality (on average one ton of lignite is equivalent to 0.3 tons of hard coal) and the ratio of overburden to coal thickness. Large mines over 200 m deep are in operation.

The seam thicknesses of hard coal now being worked range from about 1 m to 3 m although exceptionally thicker seams occur, and depths range to about 1,000 m. In the U.S.A. strippable reserves amount to about 60% and most of the remainder is accessible by relatively shallow

WORLD RESERVES OF HARD COAL AND LIGNITE

(proved, probable and possible)
10^9 tons

Location	Lignite	Hard Coal	Total (coal equivalent)	% of World Total
Africa				
Rhodesia	Neg	7	7	
S. Africa	Neg	72	72	
Swaziland	Neg	5	5	
Remainder	Neg	2	2	
Sub-total	Neg	86	86	2
N. America				
Canada	24	61	68	
Mexico	Neg	4	3	
U.S.A.	876	684	947	
Remainder	Neg	Neg	Neg	
Sub-total	900	749	1,018	24
S. America				
Brazil	Neg	11	11	
Colombia	Neg	12	12	
Remainder	10	3	6	
Sub-total	10	26	29	1
Asia (with USSR)				
China	100	1,011	1,041	
India	2	106	107	
Japan	2	19	20	
USSR	800	1,400	1,640	
Remainder	2	6	7	
Sub-total	906	2,542	2,815	66
Europe (without USSR)				
Czechoslovakia	10	12	15	
Germany	92	70	98	
Poland	15	46	50	
UK	Neg	15	15	
Yugoslavia	27	Neg	8	
Remainder	7	14	16	
Sub-total	151	157	202	5
Oceania				
Australia	96	16	45	
Remainder	Neg	1	1	
Sub-total	96	17	46	2
WORLD TOTALS	2,063	3,577	4,196	100

incline shafts. Underground mining conditions are considered "good" by European standards.

In Western Europe the proportion of reserves available for opencast mining is considerably lower, say 20%, with another 20% accessible by shallow incline shafts. The majority of the hard coal mined, however, comes from deep vertical shaft mines (600 m to 1,000 m) and conditions range from "medium" to "difficult". Environmental problems have restricted surface mining considerably in Western Europe and these restrictions are not likely to be eased very much as a result of the energy crisis. In the U.S.A. there has hitherto been much more freedom to operate although new operations will be seriously restricted in many areas.

The position in the rest of the world is less clear. Deep vertical-shaft mining is practised in India, Chile, Japan and Korea for example but incline drift mining is probably the most commonly used system, e.g. Australia, South Africa, Brazil and Argentina. Opencast mining has not developed to any great extent because the scale of operations has been too small and labour cheap and plentiful. However, at least 40% of the resources could be mined in this way with a further 40% by shallow mines. The deeper resources would only be developed when the shallower are running out and in fact these resources are often not even counted. For instance, in Southern Africa there has been little interest in any coal seams deeper than about 250 m.

Countries with coal resources which seem significant in the light of the present world energy situation and where they could relatively easily be developed are U.S.S.R., China, Colombia, U.S.A., Canada, Australia, South Africa and Botswana. The development of the remaining resources of Western Europe, Poland, India and Japan will be much more difficult because of the environmental, technical (depth and mining conditions) and social problems involved.

The U.S.S.R. and China will be able to supply their own energy needs and may be willing to export. Negotiations have, in fact, been in progress for some time between China and Japan and Chinese coal could be the solution to Japan's energy problem in the next two or three decades. U.S.S.R. has a record of export in oil and gas and exports some coking coal to Japan. They may well be willing to increase coal exports at the high prices which the market will bear but transport will be the main problem as the coalfields are in the interior of the country.

Government regulation of the coal industries of U.S.A. and Canada, at least as far as commercial policy is concerned, is much less than in other countries and therefore the industries are expected to respond rapidly to market forces. However, Canada does intervene to regulate exports in a number of minerals, e.g. oil, gas, potash, and would certainly do so in the case of coal if exports began to endanger their own supplies. The main obstacles are likely to be capital, manpower, environment and transport facilities.

Australia and South Africa are in a similar situation in many ways although the Australian State and Federal Governments regulate the coal industries more than in South Africa. However, South Africa is only just entering the coal export market and the Government would certainly intervene if exports increased sufficiently to endanger their future energy supplies. The 1969 assessment of coal resources caused some alarm as under one set of assumptions the reserves were predicted to last only 30 years. However, a new assessment is now in progress and this is expected to double the estimate. South Africa, because of its political situation, has always been concerned to secure its own energy sources and will undoubtedly continue to do so.

Poland has large resources of both lignite and hard coal and is a substantial exporter of the latter, both for coke-making and for power stations. The production comes from deeper underground mines and expansion is still in progress. Being a centrally-planned economy the coal has been priced on a non-commercial basis, the main objective being to obtain foreign exchange.

The developing countries are considered in some detail in Annex 3. to print

SULPHUR

Until the recent upsurge of interest in environmental pollution, sulphur content has only been of interest as a contaminant in coking coal. However, in the U.S.A. recent legislation has restricted the use of high-sulphur coal (and oil) in electric power stations and until satisfactory methods of removing the sulphur from the coal, either before, during, or after burning are evolved, low-sulphur coal will be in demand. In other developed parts of the world less concern has been expressed about stack emissions because the problem has not been so acute and generally high stacks with high emission velocities have been considered adequate (although eventually similar restrictions are expected). As a result more attention has been paid in the U.S.A. to the classification of coal resources by sulphur content.

The sulphur content of U.S. coals ranges from 0.2% to as much as 7%. The stack emission standards generally require the burning of coals of less than 0.7% sulphur but this criterion is under pressure and 0.5% is now regarded as imminent. The sulphur content of the estimated coal reserves of the U.S.A. is given below together with that of coals east of the Mississippi River:-

	Sulphur Content		
	<1%	1-3%	>3%
U.S.A.	65	15	20 %
East of Mississippi River	20	37	43 %

Most of the low-sulphur coal resources are therefore west of the Mississippi, i.e. mainly in Wyoming, Montana, and Colorado (over 20 x 10^9 tons of strippable coal). In addition, 80% of the lignite in the Middle West contain less than 0.7% sulphur. In contrast 80% of the higher rank bituminous coals of Illinois, Indiana and Kentucky contain more than 3%. The Appalachian region has large deposits of coal with coking properties but only the low-sulphur coals are used for coke making, the remainder, which contain 1% to 3% sulphur, being available for power station use.

As regards the rest of the world, the position is not clear and a detailed examination of primary quality data would be necessary to classify the resources on a sulphur-content basis. However, it is known that the coals of Europe, Southern Africa, Australia and India are generally low to medium in sulphur content.

UNKNOWN RESOURCES

The coal resources given above can be regarded as "known" at least to some extent. "Ultimate" resources have been estimated at nearly four times this quantity, i.e. 15 x 10^{12} tons and these are distributed as follows:-

	%
Asia	65
North America	27
Europe	5
Africa	1.4
Oceania	0.7
South and Central America	0.2

This compares with around 2 x 10^{12} bbl of oil, i.e. 0.35 x 10^{12} tons of coal equivalent. On this basis coal resources are 43 times greater than oil resources.

No world-wide study of the sedimentary basins as a source of coal has been undertaken but the oil companies must possess a lot of information about coal from their geophysical work and deep drillings in the sedimentary basins and it is to be hoped that it was properly recorded at the time even if of no economic importance then.

Areas where unpublished coal resources undoubtedly exist are Northern U.S.S.R., Greenland, Central Asia, South America, Central Australia and the continental shelves, particularly of Northern Europe (e.g. under the southern North Sea) and Asia.

IV METHODS OF EXTRACTION

PRESENT METHODS

Surface mining methods (opencast mining, strip mining) can be sub-divided in two ways, i.e. by the type of machine and by the method of handling overburden. Machine systems may be discontinuous or continuous, the former applying to draglines, shovels, trucks, etc., and the latter to bucket-wheel excavators and conveyors. Overburden may be handled by direct-casting across the pit or by round-the-pit transport. Strip-mining as practised in the U.S.A. for instance, is a discontinuous, direct-casting system whereas lignite mining, as practised in the West German lignite mines is a continuous round-the-pit system.

Underground mining methods are mainly room-and-pillar or longwall, the former being more suitable for thick, shallow seams and the latter for thinner, deeper seams. These methods are described in some detail in Annex 4 and a number of less important methods.

Proportion of Underground and Surface Mining

Few countries publish information relative to the proportion of underground and surface mining and no figures for the world are available. However, it is estimated that surface production of coal, lignite and brown coal is about 40% of the total. The trend is for surface mining to increase as is clearly shown by the figures for the U.S.A. and the U.K. below:-

Country	Proportion of Surface to Total Production, %					
	1967	1968	1969	1970	1971	1972
United States	33.8	34.1	35.2	40.5	46.9	N.A.
United Kingdom	3.9	4.0	4.0	4.3	5.6	8.3

The reason underlying the trend towards surface mining is the much higher productivity and lower production cost, compared to underground mining. For instance, in 1970, the productivities for surface and underground mining in the United States were:-

Underground mines	12.48 tons/manshift
Surface mines	32.62 tons/manshift
All mines	17.09 tons/manshift

Percentage Recovery

In the extraction of coal, losses occur due to:-

(i) the need to leave protective pillars under surface structures to prevent subsidence, or against old workings to prevent the ingress of water or gas.

(ii) the system of mining employed which may necessitate forming pillars to support roadways or working places or leaving coal bands to protect the roof.

(iii) unfavourable geological conditions, poor quality coal, thick dirt bands, faults, etc.

(iv) the need to mine selectively owing to small profit margins or to inferior quality coal bands in the seam.

When recovery figures are given, they may be expressed either in terms of the percentage of in situ coal extracted or as a percentage of the workable reserves recovered, i.e. after allowing for losses due to (i), (iii), and (iv) above.

A coal mine in South Africa has been planned to extract only 22% of the in situ reserves in order to cut production costs. Few mines record the percentage of coal actually recovered systematically and there is some concealment of the true position. Concern has been expressed in many countries about the obvious wastage of coal resources currently taking place. The room-and-pillar system is worse in this respect than longwall as it uses coal to support the roof whereas longwall uses steel, typical recovery percentages being 40% and 80% respectively.

REVIEW OF CONSTRAINTS

Surface Mining

Surface mining, as discussed elsewhere, is limited to relatively shallow deposits in country areas by the economics of overburden removal and land rehabilitation. Some of the main curtailments on operations are:-

(i) Economic depth of mining - the cost of progressively deeper overburden removal, coal loading and land reclamation, relative to the cost of exploitation by underground methods, determines the economic depth.

(ii) Land usage and scenic despoilation - the whole operation from start to finish should be considered as "land sculpture" and not a quick rape of the resources.

(iii) Ancillary costs - e.g. infrastructure, housing, coal transportation, etc., can substantially increase the cost in more remote areas.

(iv) Power supplies - the practical size of excavators can be limited by the capacity of the electrical distribution network or mine power station to absorb cyclic loads.

(v) Surface topography, i.e. steep slopes, and also seam inclination constrain the extent and method of surface mining.

Environmental Impact and Restoration

Reclamation of mined-out areas requires responsible land management and has to be allowed for in planning and costing operations. It is to be remembered that not only surface mining but also underground mining of thick deposits with high recovery rates can cause serious surface damage by subsidence. However, in both cases it is possible to restore the landscape to first-class economic use.

Many Governments require operators to make provision for restoration. A levy may be charged on mine output or a bond may be required to be deposited to cover restoration costs.

Systems of reclamation may be limited to afforestation or grassing of the roughly levelled spoil heaps. The resultant woodlands, apart from their economic value, also provide recreational areas especially in flat, featureless country. Alternatively, complete reclamation may be required, including drainage contouring, up-grading of land use, road and field line improvements and new housing settlements as in some of the extensive lignite mining areas of Europe.

A feature of most opencast projects is that initially overburden has to be stacked in an elevated bank outside the mine to enable a working width of pit to be developed and finally the last advance of the mining benches remains unfilled, leaving a large, deep hole which will most likely fill with water.

The presence of sulphur in the overburden and coal of opencast mines can result in acidic effluent discharge which requires treatment before entering the river system.

Underground Mining

Technological

In the field of underground mining, there are currently available systems and equipment which enable practically the full range of seam conditions to be exploited. These seam conditions may range between the following limits:-

Thickness	0.5 m to 100 m
Gradient	Flat to vertical, but mostly less than 20° to the horizontal
Depth	Outcrop to 1,300 m

The main constraints to higher production efficiency and lower costs in underground mining are:-

(i) The limiting capacities of current getting and loading machines.

(ii) The difficulty of providing adequate support of the working faces and roadways, particularly in weak strata or where intense ground pressure is experienced.

(iii) Inadequate transport facilities from the production units underground to the despatch points on the surface.

(iv) The difficulty of cleaning certain coals where the inherent ash is finely disseminated in the coal substance or where the coal has a high sulphur content.

(v) In the advancing longwall system of mining, the speed at which roadways can be formed behind the working face.

(vi) In longwall retreating, the rate at which roadways "in the solid" can be driven.

The environment in which underground mining operations take place, affects not only the health and safety of the operatives but may also limit operational capacity and efficiency, particularly when a highly mechanised system is employed. The main environmental factors involved are dust, gas and heat.

Environmental Impact and Restoration

Although underground mines do not disturb surface amenities to the same extent as surface mines, their construction and operation may have detrimental affects on the local environment. For instance, spoil is produced both during actual mining operations and during the process of coal cleaning and has to be disposed of either by stowing underground, by tipping, or by lagooning in the case of slurries, on the surface. Many restrictions are now being placed on the location and mode of formation of spoil heaps and lagoons.

Social

Working conditions in underground coal mines are a disincentive to the recruitment and employment of operatives and officials. Also the "industrial revolution" image of the industry with its bad record in human relations, mine disasters, etc., still persists. Nevertheless, by good management and planning, it is possible to create an acceptable working environment underground and to provide good social amenities.

COST FACTORS

The capital investment needed to construct and equip a coal mine depends on a number of factors, e.g.:-

(i) The planned capacity.

(ii) The depth of the deposit and the nature of the strata over the seam.

(iii) The location of the mine.

(iv) The degree of mechanisation, both underground and surface.

(v) The preparation plant needed to prepare the coal for the market.

(vi) The size and complexity of the township and infrastructure to be constructed.

(vii) The transportation facilities necessary for coal, materials, and personnel.

Owing to the varying impact of these factors, the required capital in any particular instance can vary within wide limits as shown by the following table:-

TYPICAL COAL MINE PRODUCTIVITIES, PRODUCTION COSTS AND INVESTMENT COSTS

Method	Depth m	Recovery %	Productivity tons OMS	Production Cost US $/ton	Capital Cost/ton of Annual Output US $
Strip-mining or opencast mining	0-200	90	12-200	1-10	6-25
Adit and drift mines	10-250	30-75	10-25	3-15	15-25
Deep Mines	250-1,200	60-80	1-3	10-25	25-40

Production Costs

The production costs of coal mines also vary widely (see table above) depending on the following factors:-

(i) Level of production

(ii) Method of mining adopted

(iii) Geological conditions (particularly stripping ratio)

(iv) Degree of mechanisation

(v) Salary and labour rates

(vi) Cost of materials, spare parts and energy

(vii) Method of financing, depreciation policy, etc.

(viii) Taxation and mineral royalties

(ix) Overhead charges including housing, social charges, transportation of coal and personnel

(x) Degree of coal preparation required and the "yield" of clean coal.

The costs refer to the saleable product, i.e. after any treatment and no account is taken of the quality of the end product.

<u>Cost Range</u>

The range of production and investment costs given above indicates the need for examining each mining proposition on its merits. Valid comparisons on a production cost basis are only possible between mines working close together in the same coalfield where they would be expected to be subject to the same conditions and constraints. Furthermore the cost of transportation to markets outside the coalfield frequently exceeds the production cost and such projects must be assessed on the economics of production and delivery to the market.

FUTURE DEVELOPMENTS IN EXTRACTION METHODS

Surface Mining

With the current world-wide demand for coal, surface mining with its potential for rapid development and high output levels, is likely to extend; deeper mining limits and longer faces to encompass greater exploitable reserves will be planned along with higher production capacities. These trends will continue to encourage the use of even larger machines despite the problems which arise. Also mammoth mines will create concentrations of dereliction of land which should be easier to control than a large number of small operations.

In the case of draglines and shovels inertia forces increase as the square of the leading dimension and this factor pushes up the cost of the machine disproportionately to the benefits gained. Also in deeper mines bench and spoil heap stability may require flattening the overall slope thereby increasing the mine width to the point where direct-casting systems cannot be used.

It seems likely, therefore, that where deeper surface coal mining is required, combination spoil disposal systems will develop, e.g. direct-casting by spoil bridge or mobile stacker allied to round-the-pit conveying by belt conveyors, trucks, etc., for the higher benches as practised in deep lignite mining.

In the case of dump-truck transport, the size of units will increase and power-assisted trucking systems will also come into more common use, e.g. trolley wire power supply during travelling on gradients and main haul routes combined with diesel-electric power for bench mobility. Some investigation into the use of fast rail transport capable of negotiating gradients may also take place.

Hydraulic transport of spoil has been used on occasions, but has not been wholly successful. If however, spoil has to be transported appreciable distances for environmental or other reasons, the inherent low costs of the system merit investigation.

There seems to be no limit to the theoretical size of continuous excavators but as yet they are, in general, restricted to use in weak or medium strata. Procedures are, however, developing in the use of ground preparation by blasting to assist loading in harder strata. It is also likely that machine design will be further modified to increase digging ability in harder ground. Again crushers may have to be incorporated to reduce the lump size to that suitable for conveyor transport.

Drilling and blasting is necessary for preparing the overburden for loading in most surface hard coal mines and this is a significant factor in any mining operation both as a direct cost and by its effect on the efficiency of loading. The main explosive agent in common use, i.e. ammonium nitrate/fuel oil, is unlikely to be superseded. Drilling equipment is likely to be further developed allowing the use of larger diameter holes, even in hard strata, thereby allowing wider spacing of blast holes and fewer holes.

Underground Mining

The continuing pressure to mine coal more efficiently and at lower cost is inducing well defined changes in coal mining methods and techniques, the general trends being as follows:-

(i) Larger capacity mines.

(ii) Increasing labour costs and recruitment difficulty, leading to further mechanisation.

(iii) Higher capacity, more powerful machines and greater concentration of operations.

(iv) More exploration in advance of production allowing better mine planning.

(v) Remote control.

(vi) Improved machine design to reduce production losses due to breakdown and to facilitate maintenance.

(vii) Reduction of lead-time by applying new shaft-sinking techniques, particularly bored shafts.

(viii) Trend to longwall mining, particularly retreating systems.

(ix) Renewed interest in hydraulic mining.

(x) Advances in heading machines and support systems.

(xi) Improved mine transport systems.

SPECIAL PROBLEMS IN THE DEVELOPED COUNTRIES

The special problems facing the mining industries in the developed countries at present can be discussed under the headings output, image, labour, staff and economics.

The output problem is how to expand present production rapidly to meet the sharp increase in demand. The industry is relatively inflexible, particularly the ageing coal-mining industries of Europe and Japan with their preponderence of underground mines. Furthermore, this involves a reversal of trends over the last decade (4.1% per annum decline in Europe).

The image of the coal industries of all the developed countries in the eyes of the general public is bad. The changed economic climate, however, will provide an opportunity to correct this, but it will take some time and much effort to eradicate the legacy of past and current failings. The value of coal to society may now be increasingly recognised, but there seems little hope of attracting the staff and labour required until the industry has a bright modern image.

The labour supply situation is closely linked with the public image. The labour forces are ageing, e.g. 63.6% of the wage-earners employed in the U.K. National Coal Board in 1971 were over 40. The problem of recruiting and retaining young men is very serious. Increased pay will help, so also will any reduction in alternative job opportunities resulting from an economic down-turn, but these factors will not be decisive. The use of immigrant labour, e.g. West German, is no long-term solution.

The recruitment and retention of technically qualified staff is a major problem which begins when schoolboys are considering a career. Mining, particularly coal mining, is low on the list of possibilities, and as a consequence university entrants tend to be of lower ability than average. Again the image of the industry is responsible for this state of affairs. Also the run-down of the coal industries, particularly in Europe, has resulted in fewer mining courses being offered at the universities. Furthermore, the social environment in mining areas has been unattractive to young technologists. Career prospects are not, therefore, regarded very favourably.

The economic problems of the coal industries have largely stemmed from the running-down or restricted growth situation of the last 15 years, but the rise in the opportunity cost of alternative forms of energy provides leeway for a better future. Where private enterprise can flourish more or less untrammelled by Governments, the main problem is likely to be that of attracting sufficient capital in competition with other opportunities. Surface mining has a considerable advantage here, because of the shorter lead times and hence better cash flow.

SPECIAL PROBLEMS IN THE DEVELOPING COUNTRIES

The developing countries suffer from most of the problems of the developed countries, with the exception of the absence of traditional attitudes in many cases. Opportunity therefore exists to avoid many of the traditional problems of the industry. However, a whole range of new problems obtrude, e.g. remoteness, absence of infrastructure, lack of skills, lack of finance, shortage of foreign exchange, etc. When foreign entities apply for mining rights, there is suspicion of exploitation and also resentment when skilled expatriates are engaged at high salaries. Many countries need objective guidance in the formulation of mining policies for the utilisation of their coal resources to their best advantage. Unfortunately, the better-educated section of the population is not attracted to mining but as the educational base expands, perhaps this problem will lessen.

V WORLD COAL PRODUCTION

PRESENT PRODUCTION

The world production of hard coal and lignite in 1972 is given in the following table. The world total represents about 35% of the total world production of primary energy, liquid fuels being about 43%, natural gas 20%, and hydro and nuclear 2%. The actual production of solid fuel fell by over 100 million tons of coal equivalent from 1970 to 1972 and the share of world energy production has been falling steadily since 1950.

92% of the production of Africa came from South Africa and about 2 million tons of that were anthracite.

In North America 95% of the production came from the U.S.A. including about 140 million tons of coking coal, 8 million tons of anthracite and 26 million tons of lignite. Most of the remainder came from Canada with Mexico producing only a small quantity of hard coal.

In South America the small total production was all of bituminous coal and it came from Colombia, Brazil, Chile, Argentina and Peru. Very little was of good coking quality.

The two main coal producers of Asia are the U.S.S.R. (including European Russia) and China. In the U.S.S.R. 35% of the hard coal produced was of coking quality. 75% is at present mined in European Russia but this proportion will decline as the vast coalfields of central and eastern U.S.S.R. are developed.

WORLD PRODUCTION OF HARD COAL AND LIGNITE BY CONTINENTS (1972)

10^6 tons

Region	Hard Coal	Lignite	Total (coal equivalent)
Africa	64	Nil	64
North America			
U.S.A.	470	26	478
Remainder	20	8	22
	490	34	500
South America	8	Nil	8
Asia			
All U.S.S.R.	494	155	540
China	300	7	302
Remainder	120	12	124
	914	174	966
Europe	516	587	692
Oceania	59	25	67
TOTAL	2,051	820	2,297

The figures given for China are uncertain because of the lack of published data. A large proportion is anthracite and production of coking coal is sufficient for domestic uses. India (74 million tons) and Japan (28 million tons) are large producers although both have severe production problems. Six other countries produce 19 million tons between them.

In Europe coal production decreased at the rate of 4.1% per annum during the last decade but it is still substantial, the main producers of hard coal being Poland, U.K., Germany, France and Czechoslovakia in descending order. Eleven other countries produced some hard coal. This coal is generally of high quality and relatively low in sulphur. 25% is coking quality. East Germany, West Germany, Poland and Czechoslovakia are substantial producers of lignite but significant tonnages are also produced in Yugoslavia, Romania, Bulgaria, Greece, Turkey, Italy, Austria, France and Spain.

The Oceania region is completely dominated by Australia which produced 99% of the hard coal and nearly all the lignite. In fact, production has been increasing at the rate of 7.2% per annum over the last decade, much of it for export (21 million tons 1971/1972). 40% of the coal and all the lignite is mined by opencast methods at low cost. Sulphur content is generally low and 65% of the hard coal output consists of coking coal.

Capacity of Existing Mines

The capacity of existing mines varies from a few tons per day to over 50 million tons per annum, the former being the output of one man scratching about on the outcrop and the latter being the output of an opencast lignite mine. In the U.S.A., the average output of underground mines (2,400) is about 104,000 tons per annum and of strip mines (2,800) 90,000 tons per annum, however the fifty largest mines (26% of total output) average 2,400,000 tons per annum for underground mines and 3,320,000 for strip mines. The largest strip mine produces about 6,500,000 tons per annum. Due to economies of scale and concentration of management effort, large organisations favour large mines but there is no doubt that the small operation will continue to flourish as prices increase. In developing countries small mines could be encouraged as

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the demand on skills and capital are low and some production can be quickly obtained.

In the U.S.S.R. there are fewer small operations and new mines tend to be very large. The position in China is obscure but seems to be similar although one would expect many small operations in such a country.

In Europe negligible output is obtained from very small operations although these are quite numerous. The 280 underground mines of the U.K. average 500,000 tons per annum, the largest producing about 2,500,000 tons per annum. The underground mines in Germany, France, Belgium and Holland average 1,200,000 tons per annum. Opencast hard coal mines in Europe are small but the lignite mines particularly in East and West Germany, Poland and Czechoslovakia reach outputs of up to 50 million tons per annum.

In Australia the 78 underground mines have an average capacity of only 430,000 tons per annum but the 6 largest hard coal strip mines produce an average of 2 million tons per annum each. In Victoria the three opencast lignite mines produce about 25 million tons per annum and output is planned to increase to 33 million tons per annum this year.

<u>Resources used in Production</u>

An indication of the capital invested in the coal industries of the world can be obtained from the table given in IV (1973 prices). Taking an overall average investment of $22 per ton of annual output the overall investment in world coal industries would be of the order of $\$50 \times 10^9$.

The labour employed can similarly be based on an overall average productivity of about 5 tons per manshift, i.e. about 1,200 tons per man year, giving an indicative total labour force of about two million.

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Materials consumption is much more difficult to estimate since the requirements of an underground mine are vastly greater than for a strip mine. Steel, in the form of roof supports, structural steel, reinforcement, tracks, pipes and machinery spares is the main item and an overall average consumption of 1.7 tons per 1,000 tons of output gives a total consumption of the order of 4 million tons per annum. Wooden supports are still used in some countries and there is a substantial consumption of rubber and plastic conveyor belt, fuel, lubricants, etc.

Taking an overall average of 25 kWh per ton of output the total electrical energy consumption is of the order of 58,000 GWh per annum.

Productivity

Typical labour productivity (OMS) figures are given in IV and the wide range from 1 to 200 tons per manshift reflects the widely different circumstances. The larger figure applies to very large opencast mines which are very capital intensive. At the lower end of the scale deep underground mines are labour intensive and strenuous efforts to raise labour productivity by greater mechanisation have recently yielded only marginal improvements. In the developed countries coal-face mechanisation has already reached over 90% and future improvements are likely to come from ancillary operations such as tunnelling, haulage, etc. Where there is a supply of cheap reliable labour, e.g. South Africa, full mechanisation is not regarded as economic.

Economy of Scale

The most striking economies of scale are seen in opencast lignite mines where geological conditions permit the use of very large excavators and conveyor systems. The largest excavators in use weigh up to 10,000 tons and cost about $40 million. Needless to say, machine availability must be extremely high in these cases. On the other hand, in the case of deep underground mines it is more difficult to increase size and any mine producing more than 2 million tons per annum is regarded as a large mine. Bottlenecks are the rate of construction of access tunnels and the capacity of shafts and tunnels for mineral transport and ventilation.

POSSIBLE EXPANSION OF PRODUCTION

It is not possible at this time to forecast with any degree of accuracy what the expansion of coal production will be in the next few decades. However, there will certainly be a considerable increase as powerful economic and political forces are operating to bring this about. On the other hand, the many problems of the industry make it relatively inflexible in this respect - particularly deep underground mining in the traditional areas, although most mines have an in-built flexibility of around 10%. Furthermore, the industry has an in-built wastage factor due to depletion of reserves and also, in many areas, a history of decline.

Taking the average life of a coal mine as 30 years (it is 52 years in U.K.) the annual replacement in capacity would be at the rate of 3.3% per annum. The rate of expansion of world coal production over the last decade was 1.8% per annum (4.1% decline in Europe) out of an expansion in total primary energy of nearly 5% per annum. Assuming that all the increase of primary energy production over the next decade is supplied by coal but that economic growth would decrease to about 3% per annum, the increase in coal production would be about 9% per annum. Assuming that about 275 million tons coal equivalent of oil was burnt in the power stations of the world in 1972 and that all this were replaced by coal over a period of 10 years, the expansion of coal production resulting would be 1.2% per annum. The total expansion in production capacity over the next 10 years would therefore be as follows:-

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	% per annum
Depletion	3.3
Total increase of primary energy	9.0
Replacement of oil in power stations	1.2
	13.5

This represents a doubling of capacity in less than 6 years - an impossibility on a world basis. 7% per annum represents a doubling in almost 10 years. Taking this figure as a possibility, this represents in order of magnitude the creation of new capacity of at least 160 million tons per annum every year. The output in 1980 would be 3,950 million tons and in 1990, 7,800 million tons.

RESOURCES REQUIRED FOR EXPANSION OF PRODUCTION

In order to meet such an expansion in capacity an annual investment of the order of $\$5 \times 10^9$ (at constant prices) will be required. The labour force will have to be expanded at the rate of about 70,000 men per year. The supply of materials and equipment should not present any problem, except to those countries which have to import supplies and which have foreign exchange problems. The expansion in number of coal technologists (geology, mining and processing) required to carry out this programme would be of the order of 1,000 per year but unfortunately the lead time to educate these up to the point of usefulness is at least 7 years. This may well be the main constraint.

IMPLICATIONS OF MINING DEVELOPMENTS FOR DEVELOPING COUNTRIES

A new mining project has a profound effect on the social and economic life of the local community and also on regional and national economies. The impact will be dependent on the size of the new project in relation to other economic activities in the area. The main implications of a new project in developing countries may be summarised as follows:-

(i) There will be increased employment opportunities for skilled and unskilled workers, for tradesmen, clerical workers, and technologists.

(ii) The additional employment provided by the new project has two effects: a multiplier effect resulting from the expenditure of the income generated by the project and a linkage effect which is the increase in income generated by the additional activity created by the project in industries which supply its inputs and process its outputs.

(iii) A new mining project necessitates improved social amenities and infrastructure including housing, roads, communications, schools, shops, recreational facilities, water supplies, power, sewage disposal, etc. These improved facilities may have to be provided by the mining company and be a charge on the project.

(iv) A coal mining project may have a significant effect on the national balance of payments. During the construction stage, the importation of skills, machinery, and materials will adversely affect this balance. If the objective of the project is to export coal, either directly or as electrical energy, once production has started, the balance of payments will benefit. Similarly, if a country has been importing fuel and the objective is to become less dependent on foreign supplies, there will also be a benefit to the balance of payments.

(v) A coal mining project contributes to the national budget through the payment of duties, taxation, mineral royalties, etc.

(vi) The development of a mining enterprise disturbs the traditional tribal way of life and customs in the locality which can lead to social problems.

(vii) As coal mining is an extractive industry, the position must be faced that, when the economic reserves are exhausted, the mine will close. Adequate plans must therefore be made to provide alternative employment for the personnel displaced well in advance of this event.

VI WORLD COAL CONSUMPTION

PRESENT CONSUMPTION

The distribution of world coal consumption by geographical region and by end use is given in the following table expressed in terms of standard coal equivalent. The world total is 2,294 x 10^6 tons which is somewhat more than the 1972 production figures given earlier. Reconciliation between statistics of production, consumption, imports and exports and stock changes is not possible and some of the figures are unreliable.

WORLD COAL CONSUMPTION (1970)
(10^6 tons coal equivalent)

Area	Iron and Steel	Electricity Generation	Industry	Domestic	Total Consumption
Europe	126	152	50	45	373
C.P.E. Europe	139	343	229	80	791
C.P.E. Asia	27	35	130	88	280
Far East	66	28	53	2	149
Middle East	2	2	2	2	8
Oceania	7	27	6	-	40
N. America	87	289	188	17	581
Africa	6	25	26	2	59
S. America	5	4	4	-	13
WORLD	465	905	688	236	2,294

Iron and Steel Industries

General economic growth and particularly the expansion of most steel using industries throughout the world has been reflected in the increased output of iron and steel. World crude steel and pig iron production amounted to 985 million tons in 1969, which resulted in the consumption of 268 million tons of coke.

The following table shows the total coke consumption of the iron and steel industries in 1969.

COKE CONSUMPTION OF THE IRON AND STEEL INDUSTRIES (1969)
(10^6 tons)

Western Europe	74
Eastern Europe	18
North America	61
Japan	33
Australia	4
U.S.S.R.	52
Rest of the World	26
World total	268
Coking coal equivalent (75% yield)	357

Steel production is, of course, heavily dependent on the level of economic activity and since this is now declining throughout the world the demand for steel will also decline. This will be offset to some extent by the extra demand created in the energy industry itself due to the expansion of alternative sources of primary energy and conversions. The coke rate has been steadily falling due to improved blast furnace techniques and such methods as oil injection. However, this trend will probably be halted for a time.

Electricity generation provides the best opportunity for expansion of solid fuel consumption. In 1970, O.E.C.D. Europe, North America and Japan consumed 177 million tons coal equivalent of oil in power stations and on a world basis this would be of the order of 275 million tons. The first objective is to transfer as much of this as possible to coal and ultimately to phase it out altogether.

Industrial uses are multifarious and there is considerable scope for changing over to coal at least for the production of heating steam and hot water, as soon as coal supplies permit. The investment required in an individual factory would not be very great. The rapidity with which the reverse changeover from coal to oil occurred a decade or two ago is indicative of what can be done if there is economic incentive and plentiful supplies.

The domestic markets are still substantial particularly in Europe but it is unlikely that there would be a sharp reversal in the declining trend because people have become used to convenience fuels.

Other uses not classified in the table above include railways which were big consumers of coal at one time. It is not very likely that the steam locomotive will make a come-back even in a modern form but electric traction should receive a boost relative to diesel.

WORLD COAL IMPORTS, 1970

The total actual coal imports for 1970 for the following geographic locations were as follows:-

	million tons
Central and South America (mainly Brazil)	4
East Asia (mainly Japan)	57
Western Europe	60
TOTAL	121

FIG. 4

AVERAGE PITHEAD PRICE OF COAL — UK 1882 — 1972

NOTE:
THE VALUE OF STERLING £ RELATES TO 1972
WHOLESALE PRICE INDEXES HAVE BEEN APPLIED

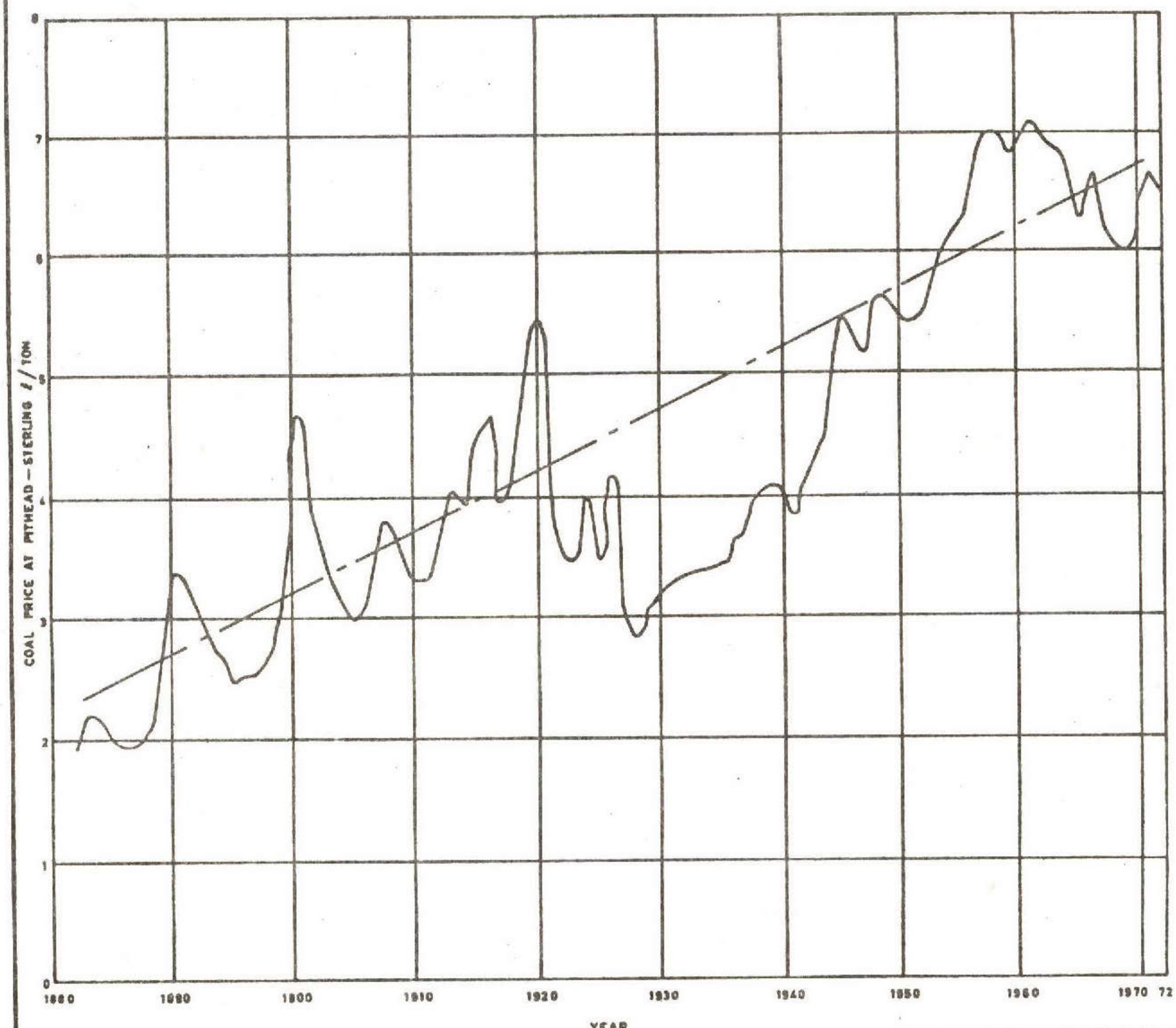
SOURCES:

1882 — 1928 .... JONES, CARTWRIGHT & GUÉNAULT

1928 — 1938 .... H.M.G. MINES STATISTICAL SUMMARIES

1938 — 1945 .... COURT

1946 — 1972 .... N.C.B. ANNUAL REPORTS



Powell Duffryn Technical Services Ltd., London		
Eng'r	Date.	Drg. No.
S.C.B.	April. 74	554/3

The main suppliers were North America (48%), the Centrally Planned Economies (mainly U.S.S.R. and Poland) (35%) and Oceania (Australia) (17%). These figures do not distinguish between different types of coal but bituminous coal of coking quality predominates.

The position with low-volatile coals (anthracite and semi-anthracite) has fluctuated remarkably over the five-year period 1966 to 1970. The reasons for these fluctuations in imports may well lie in the dual use of the fuel, i.e. domestic smokeless fuel and metallurgical. The domestic demand is falling rapidly but the metallurgical demand is increasing, although erratically. Anthracite is being increasingly used in some countries, e.g. Japan, France and Italy, also low-ash, low-volatile, low-sulphur coal is in demand as a coke blend or for formed-coke production.

DEMAND IN THE DEVELOPING AREAS

The production, trade and consumption of solid fuels in the developing areas for 1970 are given in the following table:-

(10^6 tons, standard coal equivalent)

Area	Production	Imports	Exports	Consumption
Africa including Middle East	66	2.5	3.3	65
Central and South America	9	4.2	Neg	14
Asia, excluding China and Japan	88	1.1	0.8	89
Total	163	7.8	4.1	168

FUTURE CONSUMPTION

In the developed countries the growth of consumption of coal of all kinds due to the oil crisis will depend on the following factors:-

(i) The level of economic activity will determine the demand for coking coal and other types of coal for metallurgical purposes.

(ii) The output of lignite and low-grade coal will continue to expand at the maximum rate possible, supplying coalfield power stations (surface mines).

(iii) The use of indigenous deep-mined coal will be limited by the long lead-times for new mines and the social problems involved.

(iv) There will be a big demand for imported power station coal in Europe and Japan and this will ultimately result in the siting of power stations on the coast.

(v) Pricing policies will be particularly important in determining the international trade in coal.

(vi) Pricing and supply policies adopted by the oil producers will provide the incentive to change over to coal provided that coal prices do not rise too far and also that coal supplies are reliably available.

In the developing countries policies will be dominated more by practical considerations than by market forces as far as their own consumption of energy is concerned. Indigenous coal should be developed as fast as possible both to replace imported oil and also to take advantage of export opportunities. For those countries with resources of suitable coal, small-scale synthetic oil plants could be important. The strain on scarce foreign exchange resources will become unbearable and oil substitution therefore an urgent necessity.

CONSTRAINTS ON SUPPLY

The factors of production required to expand output are discussed elsewhere but it is evident that the production of the present stock of mines cannot be expanded rapidly and the lead-times for the establishment of new mines are such that demand will continue to exceed supply for some time to come. The lead-time for a medium-sized opencast mine could comprise about two years for the establishment of the geological data followed by a further two to three years to design and equip the mine. These times would also apply to a shallow drift mine but for a deep underground mine they could well be doubled. An important constraint will be the number of trained technologists available which will determine the number of projects which can be handled simultaneously. In remote areas, of course, infrastructure requirements will be very substantial but at least these activities do not require the services of scarce mineral technologists.

Constraints on the growth of consumption of coal will be the availability of suitable appliances and the inertia of the consumer. The manufacture of solid-fuel appliances of all kinds, with the exception of power station boilers, has declined but it could fairly readily be expanded again to meet demand - particularly if general economic activity declines.

PRICES

General

This subject is one of great difficulty and is far beyond the scope of this paper, however, an attempt is made to set the scene. The ending of the post-war sellers' market for coal around 1958 resulted in considerable secrecy in coal pricing and also a plethora of subsidies of various kinds (up to over $20 per ton in some cases), particularly in Europe, so that the price structure was and still is very distorted. Furthermore there are great differences between the two types of market, i.e. internal and export, and the two main types of coal, i.e. coking and thermal.

Historic Prices

Examples are given in Annex 5 of historic coal prices reported by a number of authorities for U.S.A., U.K., Canada, Australia and West Germany and an attempt has been made to put them on a common basis (1972 values) in Fig. 3. The West German figures do not include lignite, which is largely internally traded within the electric utilities which mine it. Fig. 3 indicates that prices remained substantially constant in real terms from 1955 to 1972 with the exception of West Germany. Also it illustrates the much higher prices prevailing in the deep mining areas of Europe compared with the shallow mines and strip mines of U.S.A., Canada and Australia. Fig. 4 gives the U.K. price trend (1972 values) from 1882 to 1972, i.e. a growth rate of 2% per annum.

Coking coal is not dealt with in detail but a summary of Japanese coking coal contracts current in 1971 is given in Annex 6. Prices are heavily dependent on demand in the world steel industry and on quality.

Future Prices

In the case of internal markets the national interest requires that prices of thermal coal should be as low as possible since energy is an important cost factor in all other forms of production but the end of the low-cost energy era will have to be recognised and prices allowed to rise sufficiently to bring about economies in usage, reduce subsidies, improve the return on investment, achieve a high rate of development of new resources and retain and attract the required work force.

The main constraint on the rate at which internal prices will rise is the fear of adding to the inflationary spiral, however in real terms it seems likely that increases of around 15% per annum will occur for the next few years in Western Europe and Japan with considerably lower increases in U.S.A., Canada, and Australia.

As far as export markets are concerned it must be understood that apart from coking coal, some thermal coal trade between adjacent countries and the special case of Poland, there was no international market for thermal coal prior to the oil crisis. However, it has now made an entry into the international energy market, the only other significant competition being oil. Therefore its price will ultimately be set in relation to that of oil, after allowing a period to build up market confidence and contracts. This assumes, of course, that sheer scarcity of energy supplies does not excessively intensify competition to procure them.

In order to calculate the opportunity value of thermal coal in this market, the yardstick taken is the current average market price of crude, i.e. $8 per barrel FOB Persian Gulf, and the likely transport costs to the main markets added to give the CIF prices there. The resultant prices are given in the following table:-

TYPICAL PRICES OF STANDARD COAL
(U.S. $ per ton)

	Country of Origin				
	U.S.A.	Australia	Poland	Canada	South Africa
CIF Japan	32	32	32	32	32
CIF Western Europe	34	34	34	34	34
FOB for shipment to Japan	20	26	18	26	24
FOB for shipment to Western Europe	25	25	31	22	26
FOR for shipment to Japan	16	23	11	20	18
FOR for shipment to Western Europe	22	22	24	16	20

The following assumptions have been made:-

(i) Heavy fuel oil will cost the same as crude, i.e. will not be subsidised nor carry refining costs.

(ii) Conversion to standard coal on a calorific value basis.

(iii) 20% deduction to compensate for the higher handling and firing costs of coal.

(iv) 20% incentive.

Any further increases in crude prices will of course have the automatic effect of raising these prices, i.e. for $1 per barrel increase, all the prices would rise by about $3.50 per ton. Spot prices for crude have reached $17 per barrel and in a similar way spot cargoes of coal would occasionally sell at double these prices. In other words, a degree of market stability has been assumed.

Coking coal prices will obviously not drop below thermal coal prices but the premium will vary in accordance with demand in the case of spot and short-term contracts. At present it seems to be about $5 per ton in Europe and Japan.

SUBSTITUTION OF OIL BY COAL

Power Stations

Undoubtedly the easiest form of substitution is by raising the operating hours of coal-fired power stations and correspondingly reducing the operating hours of oil-fired stations. After that, when coal supplies become available, the conversion of oil-fired power station boilers could be contemplated. This presents many problems because of the absence of coal-handling, pulverising and ash-handling plants and would involve major re-building.

Manufacturing Industry

The following major manufacturing industries are large consumers of oil:-

(i) Fertilisers

(ii) Petrochemicals

(iii) Iron and steel

(iv) Cement

(v) Pulp and paper

(vi) Machinery and metal processing

With the exception of petrochemicals all these industries were formerly based on coal and could therefore revert to coal, either directly for heat production or indirectly in the form of coke or gas. The development of modern gasifiers capable of producing clean gas of high calorific value would greatly facilitate this changeover.

Small-scale industrial appliances will be difficult to convert but easier to replace as they have a shorter life and are not too expensive. The re-development of both large and small self-contained plants to produce pulverised fuel which could be fired in existing boilers would be useful (these were common about 30 years ago).

Gasification and Liquefaction Plants

The rapid development of these plants would, of course, result in a large demand for high volatile fuels such as lignite and bituminous coal. Large developments can be expected in Germany based on lignite which is ideal for this purpose and where a substantial history of these techniques exists. Australian lignite may also be used - East Germany is now advising in this connection. In North America also there is likely to be rapid development, but based largely on bituminous coal. Alternatives to coal are, of course, oil shales and tar sands but the yields of liquid and gaseous products in those cases are much lower.

VII WORLD TRADE IN COAL

Coking coal accounts for 80% of all seaborne coal trade, which in itself is second only to iron ore in the trade in dry bulk commodities. Very little thermal coal is as yet traded inter-continentally. Only 4% (100 million tons) of the total world coal production enters the international seaborne trade compared with 40% of crude oil production.

Japan with her meagre resources of indigenous coking coal and the most vigorous steel industry in the world dominates the world seaborne coal trade - nearly half of the tonnage and three quarters of the ton-kilometres.

The U.S. is the world's largest exporter of coking coal and Japan her biggest single customer. In 1972, Australia displaced the U.S.A. as Japan's leading supplier and the overall shift in the patterns of trade is illustrated in the following table published by Fearnley and Egers Chartering Company Ltd., Oslo:-

COAL - TOTAL SEABORNE TRADE 1972

10^3 tons

From: / To:	East Europe	Other Europe	North America	Australia	Others	World 1972	World 1971	World 1970
UK/ Continent	6,732	2,426	9,134	1,796	805	20,893	20,238	21,316
Mediterranean	4,158	2,988	4,000	893	416	12,455	12,245	12,800
Other Europe	7,325	457	2,300	100	173	10,355	10,824	12,821
South America	128	-	2,521	-	-	2,649	2,916	2,894
Japan	3,727	-	23,916	20,560	649	48,852	46,259	50,274
Others	198	47	5	250	200	700	1,404	1,080
World 1972	22,268	5,918	41,876	23,599	2,243	95,904		
World 1971	21,584	7,737	42,373	19,330	2,862		93,886	
World 1970	22,424	7,328	51,393	17,329	2,711			101,185

The annual share of anthracite in the world coal trade is about 5 million tons, mainly for metallurgical purposes, but also in some older cement-making operations. Because of its small share, non-metallurgical coal is rarely identified in coal trade figures and further research would be required to accurately quantify its present level.

The dominant marketing influence in the coal trade since the mid-1960's has been the negotiation by Japan's steelmakers of a series of 5, 10 and 15 year contracts for the supply of coking coal to very stringent specifications (see Annex 6). Supplies under these contracts tap virtually every significant available source on a world-wide basis, i.e. Australia, Canada, Poland, South Africa, U.S.A., U.S.S.R. and even "small shipments of unwashed coal" from India. The supply agreements are complemented by contracts of affreightment for bulk shipment, often of 2 or 3 years' duration or by employment of Japanese ships or ships under period time-charter to Japanese shipping companies. In 1971 over 66% of coal imports to Japan were effected by Japanese flag vessels.

Shipping is mainly owned by specialist operators and rates are highly sensitive to market influences (the grain trade is significant). To ensure continuity of supplies, large shippers may agree contracts of affreightment at rates well above current spot levels. In December 1973, a fixture on the spot market was made for a 50,000 dwt vessel from Hampton Roads to Japan at $25.15 per ton. At the same time, a fixture for a 36,000 dwt vessel from Hampton Roads to Italy was made at $11.00 per ton. In December 1971, the equivalent rate was around $4.

Ship sizes have steadily increased over the years and the economies of large-scale operation have resulted in a reduction of unit shipment costs. Present day terms favour the large volume producers and consumers and very long distance trades can be supported - the average trading distance for seaborne coal in 1972 was 4,600 miles (8,440 km).

INLAND TRANSPORT AND HANDLING

Large ships require highly mechanised deepwater loading and discharging terminals and these, in turn, demand well-organised block or unit train systems for effective operation. The physical problem of land transport and intermodal handling have made the trade in coal so much less attractive than oil. Whilst the transport of coal by pipeline is perfectly feasible, the characteristics of coal have so far limited the technique to power station applications, the best recent example being a 439 km pipeline in Arizona. The economics of the pipeline transport of coal are not well established and where a railway exists, there is no doubt that bulk rail transport is cheaper. Indicative pipeline capital and operating costs are respectively U.S. ¢5 to U.S. ¢8 per ton/km per annum capacity and U.S. ¢1.5 per ton/km.

Where inland waterways exist or geographical conditions are favourable to their development, barge transport can form a very economical link in the transport chain and is practised very extensively in the U.S.A. and Europe.

Other major inland movements are - from Poland into Eastern Europe (mainly by rail) at the level of some 15 million tons per year (1972), from U.S.S.R. to the Centrally Planned Economies (mainly by rail) at a level of some 16 million tons per year (1972) and from U.S.A. into Eastern Canada (mainly via Great Lakes shipping) at the level of some 16.5 million tons (1972).

COAL TRANSPORT COST

Guideline transport costs for various modes are shown in the following table:-

TRANSPORT COST ESTIMATES
FOR BULK SOLID MOVEMENT (1972)

Transport Mode	One-Way Distance km	Transport Cost U.S. ¢/ton km
Ocean freight -		
10/20,000 dwt	11,000	0.061
20/30,000 dwt	11,000	0.055
30/50,000 dwt	11,000	0.034
50,000 + dwt	11,000	0.028
Slurry pipeline	600	1.50
Coaster	336	0.53
Barge	-	0.14
Unit train	475	0.41
Standard train	475	0.96
Road Haulage (1,600 km/wk)	200	4.03
400 kV electricity transmission	320	0.27

A coal terminal to serve a mining hinterland producing say 5 million or 6 million tons per year for export would require an investment of $12 million to $20 million in reasonably favourable geographical conditions. The transhipment cost rail-to-ship would amount to $1 to $1.5 per ton.

OUTLOOK FOR FUTURE INTERNATIONAL COAL TRADE

As a result of the oil price increase, the opportunity value of thermal coal has increased and a world trade in coal for thermal application and/or coal products is developing. The growth of this trade might be offset, to some extent, if demand for coking coals for steel production falls off as a result of the generally forecast economic recession. There is no significant coal trade between the large energy self-sufficient regions of North America, the Middle East and Centrally Planned Economies and none will develop unless the Middle East States wish to produce their own steel or themselves refrain from burning oil in power stations.

In the outlook for coal in world energy demand, consideration of the U.S.A. and the Centrally Planned Economies can be confined to their roles as suppliers. Their internal energy policies are unlikely to have short-term effects upon the energy deficit regions of West Europe and Japan.

An immediate new demand for power station coal arises from the uprating in the merit order of coal-fired power stations against oil-fired stations, e.g. in the U.K. the increase could be 45% if the coal were available.

In Western Europe and Japan, there are a number of power stations, either converted from coal to oil-firing or purpose built for dual-fuel operation, which could easily switch to coal-firing. Conversion of existing oil-fired stations is a much more difficult operation which is unlikely to be adopted until coal supplies become readily available at favourable prices and if oil supplies become even more difficult.

It is expected that Japan and Western Europe will look towards imported coal to fulfil demand above their strategic minimum so long as supplies are available at a reasonable price, for the following reasons:-

(i) High domestic coal mining costs.

(ii) Long-term strategic advantage in using other countries' non-renewable resources.

(iii) Politically contentious situations in labour relations and environmental impact which capitalist Governments of densely populated areas would prefer to minimise.

(iv) Reciprocal trade possibilities.

(v) Good marine access.

With approximately 50% of world-known coal reserves, it is probable that the U.S.S.R. will figure increasingly in the international coal trade, both eastwards to Japan and westwards into Europe, as economic and idealogical barriers diminish.

Bi-lateral coal supply agreements are likely to develop between the energy deficit regions of Japan and Western Europe and the developing countries of South-East Asia and Africa, especially where records of political stability have been established. The quantification of possible trends in the coal trades is extremely difficult, if not impossible, at this time. Historical trend curves are of little value as the basis for past predictions has been radically modified by recent events.

Marketing developments will probably follow the pattern of Japanese coking coal imports in recent years. Also the race for control of unexploited coal resources by the international oil companies and other large enterprises will hot up. However, partnership with host governments in developing countries will become the pattern.

Many of the unexploited coal resources are relatively inaccessible and this will lead to large investments in inland transport systems, e.g. waterways where geography permits, railways using large-capacity unit tanks and pipelines in difficult country.

Developments in port-handling methods and cost are likely to follow the pattern of iron-ore installations, i.e. large stockpiles, possibly with blending, finger jetties into deep water for large ships, high-capacity ship-loaders, etc. at the despatch end and similar installations at the receiving end. Power stations and other large consuming plants will tend to be sited at the coast near deep-water anchorages. In some cases slurry handling and pipeline ship-loading and unloading systems will be favoured, particularly by the major oil companies. Oil terminal and oil tankers could be used without major modification for this trade.

The significance of this trade to those countries with unexploited resources, many of which will be developing countries, will be of extreme importance as it will be similar to the impact of the exploitation of new oil resources, although usually to a lesser degree and rather more slowly. The environmental impact will be greater. Social and economic consequences will be similar. In the case of the developed countries it should lead to a re-vitalisation of the traditional coal-producing areas, development of new areas, and considerable railway development. Power station sites will be in demand both in the coalfields and on the coast. There will be a considerable adjustment in transmission networks. These developments will of course provide considerable economic opportunities. Politically, new thinking and urgent decision-taking will be required. This urgency will, no doubt, cause even more conflict with the conservationists and the balance between economic necessity and protection of the environment will be even more difficult to strike. Some of the intensively- developed countries may find it expedient to try and "export" their social and environmental problems.

VIII PROCESS TECHNOLOGY

PRESENT TECHNOLOGY

Coal Preparation

Coal, as mined, contains inorganic impurities and dirt, and increased mechanisation has resulted in the dirt increasing and more smalls being produced.

Modern pulverised fuel power stations burn small coal, often with high ash content, but other uses require a higher grade product. This is particularly true where coal is in competition with other fuels. Various methods of segregation are possible using the differences in the physical properties of the coal and the dirt, e.g. density, resiliance or bounce, hardness, colour and surface tension.

Dry separation processes have been used, but they are inefficient and create dust problems. Wet processes are, therefore, the norm. The increased moisture in the product is not normally a problem, but dewatering methods are available.

To give an indication of costs, a modern large washery of 1,000 tons/hour throughput would cost $4 million to $6 million. Operating costs vary considerably from one country to another, but the labour requirement would be about 6 men per shift and the electricity and water consumption would be about 4 MW and 100 m^3/ hour respectively.

Coking

Coking, or more correctly carbonisation, is the process by which the volatile matter in coal is driven off leaving a carbon and ash residue. Depending on the process requirements, this residue may be powder, char or coke.

The major demand is for a hard, strong coke for use in blast furnaces and foundries. This can only be made from coking coals or from blends containing strong coking coals. The volatile matter driven off forms valuable gas and liquid by-products. By reducing the coking temperature from 1,000° C to 800° C, a semi-coke or smokeless fuel can be produced.

Town Gas from Coal

Carbonisation was also used for the production of town gas, the coke produced being a by-product. This coke residue can be used to produce additional gas of low-calorific value by two methods, i.e. water gas, producer gas, using steam and air respectively.

The use of oxygen rather than air produces a higher calorific value gas. This process operated at a high pressure can be used for the continuous and complete gasification of coal and was the most sophisticated method of town gas production before coal gasification was superseded by oil gasification. The useful constituents of these gases are carbon monoxide, hydrogen and a small amount of methane.

There are three propietary processes (see Annex 7) using this route, all producing gas in the range of 300 to 600 btu/ft^3.

Natural Gas and its Substitutes

In many parts of the world, natural gas resources are not adequate to continue to supply the increasing demand and, therefore, research has been directed to producing a substitute gas (SNG) with a calorific value of approximately 1,000 btu/ft^3. In order to achieve this, it is necessary to convert the carbon monoxide and hydrogen in the gases produced in the oxygen gasification process to methane. This conversion is called "methanation".

The first commercial plant in the U.K. using the Lurgi process and incorporating this upgrading stage has recently been built at Westfield in Scotland. There are also four commercial plants of the same type, each of 250 million cubic feet per day capacity, being built in the U.S.A.

Published figures for the American plants give capital costs of about $250 million each (i.e. $1 per cubic foot per day of output) and gas costs of $0.9 to $1.3 per 1,000 cubic feet.

Liquid Fuels

Coal liquefaction dates back to the 1930's. During World War II, Germany produced over 5 million tons of gasolene from coal. At the same time, liquefaction plants were also operating in the U.K., Italy, Korea and U.S.S.R. Since 1955, a plant consuming 4 million tons of coal per year has been operating successfully in South Africa. In all these cases, strategic considerations have been over-riding and operating costs have not been published. However, a German source has recently estimated that the same processes used now would produce motor spirit for $18 to $19 per barrel. In the past, the requirement has been to produce a high octane petrol; modern research is more towards the production of a substitute fuel oil.

Three basic principles are employed in all liquefaction processes:-

(i) Synthesis of carbon monoxide and hydrogen - the Fischer-Tropsch reaction. This is the principle used in existing liquefaction plants.

(ii) The dissolution of coal at high temperature in an organic solvent (possibly a product of the process itself), and the subsequent distillation of the solution, using the oil industry technology.

(iii) Reaction with hydrogen in the presence of a catalyst, producing both liquid and gaseous products, the latter being used as a source of hydrogen.

High Grade Solid Fuel

It is also possible to use solvent refining techniques to produce a low-sulphur, low-ash solid fuel. A 50 ton/day pilot plant now being built is reported to accept coal of practically any quality and to produce a low-sulphur pitch-like product of 16,000 btu/lb. It is claimed that this fuel can be used in existing coal-fired installations with only minimal plant modifications. However, the costs appear to be about the same as for producing a liquid fuel and it is not as convenient to transport, store or handle.

By-Products

In practice, all methods of coal conversion produce a variety of by-products in addition to the main product. In some cases, these may be an embarrassment, but they usually contribute substantially to the overall economics of the plant.

FUTURE TECHNOLOGY

Coal Preparation

There are two opposing stand-points from which the need for coal preparation can be assessed. Pulverised fuel-fired power stations can handle high ash coals and fluidised-bed combustion is also reputed to be able to handle any grade of coal, (indeed some authorities maintain it would be possible to burn colliery waste in this way). Therefore, it may well be more economic to burn unwashed coal if the extra transport and firing costs more than offset the cost of treatment. On the other hand, the metallurgical market requires coal low in sulphur and other impurities. When such naturally clean coals become in short supply, it will be necessary to turn to lower-grade sources and the importance of preparation will increase.

There are two likely developments in the plant design, firstly, greater degree of automation, and secondly, the requirement to reduce air and water pollution. The latter will require closed-circuit water systems with their associated flocculation and filtering equipment.

Coking

Good metallurgical coking coals are at a premium and this will encourage the development of processes for producing coke from non- or weakly-coking coals. These processes involve briquetting the coal with, or without a binder and carbonising. Alternatively, a char can be produced prior to briquetting. There are several variants in the pilot-scale stage, but only two are in semi-commercial production in the western world. There is also the Lurgi Spülgas process, which was originally developed to carbonise brown coal briquettes, but which is now proposed for treating bituminous coals.

Conventional coke ovens are still capable of improvement to increase capacity and improve efficiency. The recovery of gas and liquid by-products has become even more important.

Substitute Natural Gas (SNG)

A considerable amount of research and development has been carried out in the U.S.A. to find improved processes for making SNG. Seven such processes which have reached an advanced stage of development are tabulated in Annex 7. However, none of these has, as yet, got beyond pilot plant stage.

In some cases these use new methods, but in others their similarity to the Koppers-Totzek, Winkler or Lurgi processes is evident.

Reported costs are tabulated below including a Lurgi plant for comparison. It must be emphasised that the operating costs depend on low-cost opencast coal at about U.S. $4 per ton.

Organisation	Process	*Capital Cost Million $	$/10^3 ft^3
El Paso	Lurgi	250	0.90 to 1.30
Applied Technology Corporation	Atgas	160 to 200	0.70 to 1.00
Consolidated Coal Ltd.	CO_2 Acceptor	150	Below 1.00
Kellogg	Molten Salt	163	0.66 to 0.80
Office of Coal Research	Bi-Gas SNG	150	0.60 to 0.80

* For 250 to 270 million cubic feet/day plants.

Low Btu Gas

In view of the complex production processes, SNG is comparatively expensive on a heat content basis. It is far cheaper to make a low-grade gas (of 130 to 300 btu per cubic ft). This is not suitable for general distribution and is expensive to transport due to its poor heat content to volume ratio. It has, however, two important possibilities for power generation:-

(i) For firing conventional steam boilers in circumstances where the sulphur pollution, resulting from the direct combustion of coal, would be acceptable.

(ii) For use in a combined gas turbine/steam boiler complex. Under these circumstances, it is feasible to obtain a generation cycle efficiency of up to 50% compared with about 35% from a simple steam cycle.

Liquid Fuels

The processes listed in Annex 7 have reached an advanced stage of development in the U.S.A. and details of some of the reported costs are given below.

Organisation	Process	Capital Cost Million $	Output and Production Costs
Chem Systems Inc.	COG Refinery	647	Liquid 120,000 bbl/day @ $4.50/bbl Gas 332 x 10^6 ft^3/day @ $0.75/$10^3$ ft^3
Consolidated Coal Co.	CSF	250	Liquid 70,000 bbl/day @ $4.0/bbl
Hydrocarbon Research Inc.	H-Coal	318 to 332	Liquid 100,000 bbl/day @ $4.62/bbl
Office of Coal Research	COED	486	Liquid 27,000 bbl/day @ $3.80/bbl Gas 250 x 10^6 ft^3/day @ $1.65/$10^3$ ft^3

Trends in Gasification and Liquefaction

The basic technology of gasification and liquefaction is already well established. Trends are likely to be in their application rather than in basic processes. Development of gasification is at present ahead of liquefaction, as the short-term problem in the

U.S.A. is to solve their natural gas supply problem, and this is where most of the work is being done.

The significance of the contribution to the energy balance of any one country's economy is difficult to estimate at the moment, but considering the U.S.A., it has been estimated that by 1985 SNG plants will satisfy between 2% and 8% of the estimated demand. The higher figure would involve 30 plants each of 250 million cubic feet per day. Similarly, oil from coal could amount to up to 2% of the total liquid fuel demand - though it must be pointed out that any projections of demand made under present conditions must be highly conjectural.

These figures imply a greater use of gasification, but in the long term a greater emphasis on liquefaction could be expected, not only because of the present shortage of liquid fuels but also because there are intrinsic advantages of liquefaction, i.e.:-

(i) A far lower degree of hydrogenation is required.

(ii) Synthetic liquid fuel is more easily stored and distributed than SNG.

(iii) Considerably lower water requirement and less water pollution.

In the long term, it is likely that the technologies will be combined into complexes of considerable size, just as the modern oil refinery produces a wide range of hydrocarbon products. The most advanced concept, at present, is a coal-oil-gas power station complex in which it is envisaged that a gasification plant would produce pipeline gas, a low-grade gas for direct combustion, and hydrogen;

the hydrogen would then be used in a liquefaction plant, producing fuel oil for direct combustion, gasolene for the transport market, and chemical feedstocks as well. The economies of such a system have been closely investigated, and were shown to be viable even before the recent oil price rises.

Process Research Efforts

By far the greatest amount of research is being carried out in the U.S.A., and the momentum is likely to accelerate. At present, $2,000 million per year is ear-marked for research into coal gasification and liquefaction.

In the rest of the world, the policy is not so clear and it is difficult to quantify the amount of research effort being devoted to coal processing. However, it is clear that many different countries see this as a short or medium term answer to their own particular form of energy crisis.

Of the European countries, only Germany has published a programme. They propose to spend about $130 million up to 1977 on coal and nuclear research. Their programme falls into three stages. Firstly, production of lean gas for a combined gas-steam turbine cycle, then developing existing processes for producing SNG and finally, a modern oil-from-coal process.

Japan, who has been particularly badly hit by current shortages, has yet to make public its intentions, but it is likely that it will try to use current American research and development.

Price and Strategic Implications

At present oil prices, it is economic for countries with accessible coal reserves, such as the U.S.A., to process these on pure commercial grounds, irrespective of strategic considerations. However, one country where strategic implications will be of particular importance is Japan, whose manufacturing industry is based on imported oil. As its own coal resources are not great it might well become a market for the finished products of coal processing.

Recent events have shown the fluidity of economic and strategic factors. Added to these uncertainties is the difficulty of projecting demand and it remains to be seen whether a combination of factors, favourable to the processing of coal, will still exist in the 15 to 20 years that could be required before these plants make a significant impact on the energy balance.

Implications for Developing Countries

Present research is aimed at solving the problems of the U.S.A. and other developed countries. The resulting technology will not necessarily be applicable to a developing country. For instance, developments in SNG production are aimed at supplying an established natural gas distribution network. If the commitment to natural gas did not exist, the problem would not exist. For the developing countries, it will be a question of price, rather than security of supply, that will control their oil consumption. The amounts of foreign exchange required for this will encourage those countries with coal reserves to consider liquefaction plants and also the production of fertilizers and other chemicals, possibly as part of a coal-oil-gas complex. The problem is the large amounts of capital (mainly foreign exchange) required.

Outlook for Construction Facilities

Although there may be an increased demand for coal preparation and coking plants, this is unlikely to be a problem for the associated manufacturing industry. The most significant capital expenditure is likely to be in coal gasification plants. Estimates vary between 1 and 5 plants per year required globally. As much of the plant is within the capability of the heavy engineering and process plant industries, there should be no problems in general.

ANNEX 1

COAL AND ITS MODE OF OCCURRENCE

Coal is defined in the Oxford Dictionary as "Black mineral of carbonized vegetable matter found below ground ......". More technically it is a black or brown mineral formed from fossilised plant remains in sedimentary rocks of all geological ages from the Devonian, through Carboniferous (hence its name) to Pleistocene (recent).

The substance has been subjected to varying degrees of pressure, heat and geological disturbance, the older coals naturally being most affected. Pressure and heat have had the effect of reducing the moisture and volatile content and thereby increasing the carbon content ("rank") and ash. Typical "proximate" analyses ("ultimate" analysis is by elements) of the main coal types (in situ) are as follows:-

	Inherent Moisture %	Volatiles %	Fixed Carbon %	Ash %	Calorific Value kcal/kg.	Calorific Value btu/lb.
Lignite (brown coal)	55	23	19	3	2,700	4,860
Bituminous coal	2.5	33	54	11	7,000 (standard coal)	12,600
Anthracite and semi-anthracite	1	<10	78	11	7,400	13,300
Pure carbon (for comparison)	0	0	100	0	8,100	14,600
Oil (for comparison)	variable	-	-	Neg	9,100	16,400

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The calorific value is, of course, a measure of the heat content and is the main but not the sole source of economic value. "Higher" (or "gross") and "lower" (or "net") calorific values are quoted, the difference being due to the latent heat of the moisture in the flue gas. The "lower" calorific value is a measure of the available heat.

Other characteristics of importance in respect of utilisation are Swelling Index (a measure of coking property), Ash Fusion Temperature (a measure of clinker formation), Hardgrove Index and Abrasive Index (measures of the difficulty of grinding), Gray King or Fischer Assay (determination of coke and volatiles), Sink and Float Assay (a measure of amenability to beneficiation by gravity methods), sulphur determination (as a contaminant in coke for iron-making and a pollutant), phosphorous determination (as a contaminant in coke for iron-making), size analysis. The ash itself is often of interest for its pozzolanic properties and it occasionally contains substances of economic interest, e.g. uranium, vanadium, germanium.

Coal seams occur up to 50 m or more thick although usually the higher the rank, the thinner the seam, as would be expected from the greater compression and alteration to which it has been subjected. Again the younger coals occur near the surface whilst the older coals may be covered by a great thickness of overburden (1,000 m or more). The coal-forming remains were deposited in water, i.e. horizontally, and the coal seams are

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still more or less horizontal in most cases, although steep seams occur where tectonic disturbance has been especially severe. The seams are traversed by geological faults (fractures) to a greater or lesser degree and may also be absent in places due to deposition conditions, erosion, "wash-outs", intrusions of igneous rocks, etc. The coal seams are mainly associated with sandstones, shales, and fire clays and lignite seams with sands, gravels and clays.

Peat is the least useful of the solid fuels because of its high moisture content and low calorific value but it is worked in Russia, Central Europe, the Republic of Ireland and Greece. For power station fuel it is milled and air-dried on the ground and for domestic use it is cut into turves or sods, or extruded, and air-dried. The cover is either non-existent or thin soil and the "harvesting" equipment has been especially developed, particularly in respect of low permissible ground pressure. Except in a few special cases its use as a source of energy is insignificant. It is in fact not usually included in the classification of "coal" and will not be referred to again in this paper.

Lignite is a low-grade, high volatile fuel with high moisture content and low calorific value. It is light-brown to dark brown in colour, hence the alternative name "brown coal". (Some countries use both terms to describe somewhat different deposits). It is found near the surface and generally mined by opencast methods although some underground mines are still in

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operation. Its consistency ranges from earthy to fairly hard and much of it is fibrous. Ash content can vary from very low to very high. Its high volatile content makes it suitable for low-temperature carbonisation but it does not form a coke unless briquetted before carbonising. Its main usage is direct-firing in coalfield power stations. Briquette production for domestic use, railways, etc., has declined considerably. Because of its low proportion of combustible matter (20% to 50%), it is not transported any distance. The main resources of lignite are in the U.S.A./Canadian border areas, Europe, Russia, Turkey, India, Thailand and Australia.

Bituminous coal (black coal, "Steinkohle") is of higher carbon content than lignite with lower volatiles and moisture content and higher calorific value (3 to 7 times). Again the ash content is variable, depending as it does on the conditions of deposition. Most of the world coal resources are in this category and also most of the consumption. It includes a wide range of coals - low-volatile dry steam coals and coking steam coals, medium-volatile prime coking coals and high-volatile coals with coking properties ranging from non-coking to very strongly coking. The characteristics of the ash are variable and influence the application of individual fuels and the design of the appliances to burn it. The most critical in power station boilers is ash fusion temperature which if low causes the ash to melt and form sticky deposits in the cooler parts of the furnace ("clinker"). Sulphur occurs in all coals to some extent and it is significant in two entirely different aspects, i.e. as a contaminant in coke when it finds its way into iron; and as an atmospheric pollutant.

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The sulphur occurs in three forms - organic, sulphate and sulphide (mainly pyrite) and not all this sulphur appears as sulphur dioxide in the flue gas, some of it being retained in the ash. However, to meet EPA's sulphur-control guidelines, the coal must contain less than 0.7% of total sulphur by weight for coal containing 12,000 btu/lb (6,670 kcal/kg). This sulphur content is reduced by washing as most of the pyritic sulphur reports to the rejects, but the organic sulphur cannot be separated by physical means.

Anthracite is higher in carbon content and lower in volatiles than bituminous coals due to the effects of greater compression and heat and generally the same influences cause increases in density, hardness, abrasiveness, etc. Ash content again depends on the conditions of deposition but, by virtue of the loss of volatiles, all other things being equal, the ash content is increased. These types of coal are characterised by low reactivity and slow, smokeless combustion; they are non-coking.

ANNEX 2

USES OF COAL

Coal finds its main uses today in the production of heat in industry and electric utilities and in the form of coke for metallurgical processes. However, although declining it is still used for domestic purposes, railways and gas production. The by-products of coke and gas production furnish important chemicals and the ash has a number of uses in the construction industry. Some types of coal can also be used as filter media.

For the production of heat in industry, the coal is burned in shell or water-tube boilers, a variety of firing methods being used, i.e. fixed grate, travelling grate, underfeed, overfeed, pulverised. The shell boilers are a development of the old hand-stoked "Lancashire" boiler which was the source of so much criticism of coal as a fuel, by virtue of smoke emission, low efficiency, back-breaking work, etc. The modern shell boiler is now a highly efficient automatic unit but ash disposal is still a nuisance. This type of boiler has been developed to burn coal, oil or gas alternatively or in combination.

The modern water-tube boiler has a thermal efficiency of around 85% and can be built in very large sizes when it is customary to connect each boiler directly to a generator to form a unit, e.g. 500 MW. The coal is invariably fired in pulverised form and the ash is recovered at the bottom of the boiler or as dust at various points including finally electrostatic precipitators.

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For metallurgical use, coal is required in the form of hard coke which must be strong enough to withstand the weight of the furnace charge. Low sulphur is of prime importance as it reports to the iron and is difficult and costly to remove. Phosphorous and some other impurities are deleterious and in fact ash content generally must be as low as possible as it increases the amount of slag. Since coke is in great demand due to the expansion of the iron and steel industries of the world, particularly Japan, coking coals command higher prices than other types. Coke breeze (i.e. smalls) is also used for certain applications such as iron ore sintering, and also anthracite fines.

Coal originally formed the basis of the development of both the inorganic and organic chemicals industries but in the last few years it has been replaced almost entirely in the latter by oil (and natural gas) because of its low cost, higher purity and greater convenience. Direct chemical products derived from coal in the carbonisation process include tar and pitch, light oils, anthracine, naphthalene, carbolic acid, ammonia, benzine, toluene, xylenes, from which a vast range of products are still made. Basic heavy chemicals requiring coal in their manufacture include carbide, lime, chlorine, soda, etc. Cement production was formerly coal-based but has largely switched to oil. The coal itself has three main functions, i.e. a source of heat, a source of carbon, a reductant. Its basic draw-backs (apart from price) compared with oil and gas are greater difficulty in handling within the plant and the problems caused by the ash, i.e. dust-cleaning, clinkering, fouling, etc. Therefore a coal-processing plant is inherently more expensive to build and operate than one using oil or gas.

The ash itself is produced in large quantities in power stations (up to 30% of the coal burnt) and its disposal presents problems. However, the clinker is a useful material for road-making and the fly-ash (80% or more of the total in modern boilers) has useful properties which are being made use of increasingly as a stabilizing fill, as a substitute for cement in concrete-making, light-weight aggregates, block-making, grouts, etc.

ANNEX 3

COAL RESOURCES OF THE DEVELOPING COUNTRIES

AFRICA

The principal energy resources in Africa are coal, oil and natural gas with lignite and hydro-electric power trailing well to the rear. These energy resources are very unequally distributed, both geographically and stratigraphically, with the bulk of known coal reserves being in the southern half of the continent and the majority of oil and gas being in the northern half.

The coal reserves which so far have been developed to any extent lie in South Africa and Rhodesia. Mining and transport economics have precluded exploration of many known deposits but with world energy demands increasing, this situation could change.

The coal basins can be divided geographically into two groups: in the northern part of the continent, the Sahara basins and those of the northern edge of the African platform; towards the south and south-east, the basins of South Africa, Rhodesia, Malawi, the Congo and Tanzania, etc.

Generally speaking, the southern coals are bituminous with a high ash content and they sometimes have coking properties. Similarly, the northern coal basins of the Sahara platform, with the exception of the Moroccan anthracites, are also bituminous with coking properties and average ash content.

In both major groups small basins of anthracite have developed, e.g. in Morocco, southern Swaziland and northern Natal. The Swaziland and Natal deposits have been transformed into anthracite as a result of the injection of dolerite.

The estimated reserves and the production of coal and lignite in the main developing countries of Africa are given in the following table and are discussed below.

Algeria

Algeria possesses large coal basins in the south Oran region but the coal-bearing horizons are thin, being less than 1 m thick. The Colomb-Bechar coalfield, where mining is in progress, represents only a small proportion of the country's reserves with an estimated 30 million tons. There are two main seams and the coal has coking properties with 22% to 25% volatiles. In the Abadla basin very little exploitation has so far been carried out but the coalfield represents the major reserve of North Africa estimated at 1,000 million tons. The coal has coking properties with 31% to 32% volatiles.

Information on the Mezarif basin is limited as no mining is in progress. However, up to 17 coal seams are known but only two which average 40 cm in thickness are of commercial importance. The coal is of coking quality with 22% to 25% volatiles, 15% to 25% ash and low sulphur values.

All the coal produced in Algeria is for home consumption, and the existing market appears to be static. The increase in energy consumption which has taken place in the country has been met by the use of oil, although a certain amount of coal and coke

AFRICA - COAL AND LIGNITE RESERVES AND PRODUCTION

Country	Date	Coal				Date	Lignite				Comments
		Reserves 10^6 tons	Production 10^3 tons				Reserves 10^6 tons	Production 10^9 tons			
			1968	1969	1970			1968	1969	1970	
Algeria	1966	1,030	18	17	15	-	-	-	-	-	Lignite known but not mined
Botswana	1961	506	-	-	-	-	-	-	-	-	
Egypt	1966	25	-	4	-	-	-	-	-	-	
Malagasy	1963	1,000	-	-	-	1963	32	-	-	-	Sporadic mining
Malawi	1966	14	-	-	-	-	-	-	-	-	
Morocco	1960	120	451	361	433	-	-	-	-	-	Thin lignite beds known
Mocambique	1963	700	414	277	351	-	-	-	-	-	No lignite known
Nigeria	1961	350	-	16	58	1962	73	-	-	-	
Rhodesia	1960	6,613	3,273	3,362	-	-	-	-	-	-	
Sierra Leone	-	-	-	-	-	1950	2	-	-	-	No coal found
South Africa	1959	72,465	51,655	52,752	54,612	-	-	-	-	-	
Swaziland	1961	2,022	105	115	130	-	-	-	-	-	
Tanzania	1967	370	3	3	3	-	-	-	-	-	Lignite occurrences found
Zaire	1956	73	71	84	102	-	-	-	-	-	Peat deposits also
Zambia	1967	115	573	397	623	-	-	-	-	-	No lignite known
Total		85,403	56,563	57,388	56,327		107				

Notes: 1. Sources: 1. U.N. Statistical Yearbook, 1971.

2. Statistical Summary of the Mineral Industry, 1966-1970. H.M.S.O., 1972.

3. Survey of Energy Resources. World Power Conference, 1968.

4. Mineral Resources of Africa. Nicolas de Kun, 1965.

2. Reserves of coal include all classes but are not indicative of mining reserves and represent quantities in seams containing not less than 30 cm coal and not more than 1,250 m below the surface.

3. Production data for coal relate to all grades of anthracite, bituminous and semi-bituminous coal.

4. Lignite reserves represent the total amounts of all classes containing not less than 30 cm of lignite or brown coal and situated not more than 500 m below the surface.

5. Lignite production data include both lignite and brown coal.

is imported. In 1970, 80,000 tons of coal and 69,000 tons of coke were imported, presumably for the process industries.

Angola

No coal or lignite has so far been discovered in Angola but an asphaltic coal, known as libolite, occurs in large quantities. The libolite beds consist of carbonaceous matter associated with bitumen and occur in seams and pockets in country rock consisting of sandstones impregnated with bitumen. The beds vary in thickness from 0.50 m to 1.50 m. The raw material contains approximately 20% bitumen and has potential not only from the retorting aspect and production of gas and tar, but also as a fuel. Pure libolite has a calorific value of approximately 14,400 btu/lb (8,000 kcal/kg) although it is frequently contaminated with sandstone.

In spite of having an energy surplus, Angola imported almost 17,000 tons of coal in 1970.

Botswana

Botswana is a large, arid country with a small population and few known resources. However, vast coalfields have recently been proved in the Karroo rocks; reserves are said to amount to 9 million tons down to a depth of 200 m. The coal is bituminous, non-coking of low or medium quality with analyses reported as follows:-

Ash	14% to 18%
Volatiles	24% to 30%
Fixed carbon	49% to 54%
Moisture	5% to 6%
Calorific value	10,500 btu/lb (5,830 kcal/kg) (approximately)

These coalfields could be a major source of energy in the future if the transport problems can be solved.

One small mine has been opened at Morapule to supply the power station of the new Selibe-Pikwe copper mine. Both locations are on or near the Mafeking-Bulawayo railway. Commercial production started in 1973 and is scheduled to rise to 210,000 tons per annum by 1977 (power station). Output may be further increased to 640,000 or 1 million tons per annum including other consumers.

People's Republic of the Congo

The Congo suffers from an overall energy deficit, but according to the most recent data, a negligible amount of coal is imported.

At present no coal, natural gas or lignite have been discovered and the country remains virtually unexplored.

Egypt

In the Sinai peninsular coal deposits have been discovered at Ayun Musa and Jebel Maghara. The former site has thin coal seams at a depth of approximately 650 m but overlain by aquifers and has no real economic potential at present. However, at Jebel Maghara two seams have been discovered with reserves totalling approximately 25 million tons with an ash content of 5% to 30% and averaging 7%. The coal is weakly coking but suitable for blending with imported coals for use in the local steel industry.

Future development of the Sinai coalfield will depend upon political settlements and in this event the Maghara coal-field could well become an important producer of coal for Egypt.

Egypt imports large amounts of coal and coke from Russia, the coal imports in 1970 alone amounting to 495,000 tons. Coke is brought into the country in smaller amounts, the 1969 imports amounting to 73,000 tons. These imports however are for use in the processing industries, mainly iron and steel, and not as a source of primary energy.

Ethiopia

Both coal and lignite deposits are known in the country but do not appear to have any economic significance.

Gabon

No deposits of lignite or coal have so far been found nor does the country import either of these products.

Kenya

There are no known indigenous resources of coal, gas or oil in Kenya.

In 1970, 81,600 tons of anthracite were imported at a cost of Ksh. 7 million, i.e. U.S. $12.5 per ton. Of this, 62,000 tons came from Mocambique and 18,000 tons from Swaziland, the cost per ton being about the same. However, there is a tendency, for political reasons, to increase imports from Swaziland. In 1971 the total was about the same but Swaziland imports had increased to 49,000 tons and Mocambique declined to 32,000 tons. This anthracite is used entirely in the cement works near Mombasa.

Recent increases in the price of oil have made coal competitive with oil for power generation at the coast.

Libya

No coal deposits have been discovered so far, but lignite occurs at several places, the thickness, however, never being more than 50 cm. It is unlikely that these deposits have an economic future.

Malagasy Republic

Important coal deposits occur in Malagasy as well as those of peat and lignite. No coal production of any significance has been recorded recently and in 1970 approximately 21,000 tons of coal was imported. Total energy consumption in the same year was almost 450,000 mtce, whereas actual production in the form of hydro-electric power was about 15,000 mtce and provided almost half of the total electric power output.

A vast bituminous coalfield extends over more than 100 km in the extreme south-west of the country. The coal-bearing geological formation corresponds to the South African and Mocambique formations. The main features of these coals are their high ash content and the absence of coking properties. Only one seam is considered exploitable, the remainder having prohibitively high ash contents. This seam has a variable thickness of 3.5 m to 7.0 m and analyses indicate average values of 17% ash, 25% volatiles and 0.5% to 1.0% sulphur.

Run-of-mine roughly-sorted coal has a calorific value of 11,900 btu/lb (6,600 kcal/kg) but improvement in quality through washing is impossible because of the intimate mixture of ash and combustible matter. Washing to reduce the ash content to 10% to 20% would involve the loss of more than half of the coal treated thereby raising production costs to an impossibly high figure.

The coalfield has been extensively drilled and the proved coal reserves are estimated at 60 million tons with 17% ash content, but total reserves are said to be approximately 1,000 million tons. In spite of the large coal reserves, transportation problems and lack of local markets seem to preclude development of the field.

Malagasy also possesses an estimated 32 million tons of lignite some of which was mined during 1947/1948. The average thickness is, however, only of the order of 1.5 m and with a fairly low calorific value the economic potential of the deposit would appear to be limited at the present time.

Malawi

Malawi possesses two groups of coal deposits which are at the extreme ends of the country. The northern deposits in the Lake Nyasa region are related to the coal deposits of Tanzania and in the south (Shire Valley area) related to the lower Zambezi deposits. All of these coals belong to formations with a typically high ash content.

In the Livingstonia Basin, the total thickness of seams averages about 8 m, but they are generally lacking lateral continuity. There are three seams which contain as much as 12% to 40% ash, but are non-coking. Further investigations are needed to determine potential reserves.

Coal deposits also occur in the north Rukuru Basin, but these have barely been investigated. In the Sumbu-Nkombedzi Basin the coal series attain some 700 m thickness, but prospecting so far has not led to the discovery of any workable seams. The Chiromo Basin is small and heavily faulted but coal has been found, although insufficient data is available for tonnage estimates.

The low degree of industrialisation in the country and great transport distances involved have prevented any of the deposits being worked. However, in view of the large imports of solid fuel in 1970, the indigenous coal outlook could improve.

Morocco

Apart from numerous small deposits and traces of coal which are of purely geological interest, Morocco owns the only anthracite field in North Africa. The Jerada field, as it is known, is located on the margin of the High Plateaux of eastern Morocco. The coals comprise five workable seams between 40 cm and 75 cm thick with an ash content of 4% to 5% and volatiles between 5% and 6%. Present anthracite reserves amount to 120 million tons.

Morocco imported 47,300 tons of coal in 1970 and also 18,000 tons of coke. In the same year, however, 60,000 tons of anthracite and briquettes wer exported. Imports were for use in the processing industries and although the country lacks an extensive industrial base in comparison with European countries, the increase in GNP of 3.9% per annum over the past decade and annual energy consumption increase of 6.5% would seem to assure a satisfactory outlook for indigenous coal for some time to come.

Mocambique

The existence of extensive bituminous coal beds in the Zambezi River basin has been known for some considerable time, but production has so far been carried out only in the Tete region of the Moatize coal basin. In this area all of the seams are found in the Karroo series where twelve coal seams can be identified. The Moatize coal is the only low-volatile, hard-coking coal produced in Africa and offers tremendous export potential particularly to countries like Japan.

The mining area at Tete is situated some 900 km north of Beira, Mocambique's second largest port, the two places being connected by railway. Only one seam is being currently worked; this is 34 m thick containing 22 m of coal. Only 5 m of the coal are being worked at present but reserves over this width amount to 100 million tons and more than 600 million tons in total. The average analysis is ash 14% to 23%, volatiles 16% to 20%, sulphur 0.85% to 0.95% and calorific value of approximately 13,100 btu/lb (7,280 kcal/kg).

It is planned to expand production from the underground mine over the next few years to one million tons per annum, supplying 400,000 to 500,000 tons to Japan, the price quoted for unwashed coal being U.S. $11.50 per ton and for washed coal U.S. $15.00 per ton fob Beira. The limitations of the railway and port facilities are major problems however, in the development of export markets.

With the exception of the Moatize region, the coal potential of Mocambique is relatively unknown; however, it is considered that the country as a whole possesses reserves well in excess of those published so far.

Despite the production of coal in Mocambique, during 1970 over 335,000 tons of coal was imported from South Africa whereas total exports amounted to only 108,000 tons. This is partly due to the absence of north-south communications.

Nigeria

In Nigeria there are large deposits of sub-bituminous coal in the southern part of the country. Due to the civil war, the coalfields have only recently been reopened and production is rising. Nigeria could develop into a major coal-producing country.

Total indicated coal reserves are estimated at 350 million tons. Proximate analyses of the Enugu coals are: 7.9% to 26.0% ash, 32.5% to 41% volatiles and calorific values of 9,600 to 12,200 btu/lb (5,300 to 6,800 kcal/kg).

Nigeria also possesses an extensive lignite field, the main seam being over 5 m thick and several seams achieve thicknesses of 2 m to 2.5 m. Total reserves are estimated at over 72 million tons. Proximate analyses of the lignite give 10% to 16% moisture, 3% to 7.6% ash and 48.8% to 58.6% volatiles. Calorific values are 10,300 to 11,500 btu/lb (5,700 to 6,400 kcal/kg).

All coal produced in Nigeria in 1970 was for home consumption. The solid fuel fields are sufficiently large to be developed for far greater outputs provided that adequate markets can be found. Such an increase in production would however require extensive improvements in transport facilities.

Rhodesia

The coal deposits in Rhodesia are very substantial and after South Africa it has the largest reserves in the continent. Geographically the coal can be divided into two main groups: to the north in the Middle Zambezi Valley and to the south in the Sabi Limpopo Valley.

Middle Zambezi Valley

The Wankie coalfield is probably the best known in Africa, the main seam being a bituminous coal with good coking qualities, having a maximum thickness of 13 m but averaging 5 m.

The seam has an ash content which varies from 5% on the footwall to 30% on the hanging wall but averages approximately 12.8%. At this ash content, the reserves of the main seam are estimated at over 800 million tons proved with 450 million tons of probable reserves. Volatiles vary between 20% and 25% and the average calorific value is 13,500 btu/lb (7,500 kcal/kg). Production of coal at Wankie in 1970 was over 3 million tons.

Several other coal basins of sub-bituminous coal are known in this region, but reserves are generally small with high ash contents and the deposits are not worked.

Sabi Limpopo Valley

In the southern part of the country the Sabi basin contains a sub-bituminous coal with high volatiles, 10.9% ash and having high quality coking properties. Reserves are possibly large but so far no figures are available. The Bubye basin area contains vast reserves, estimated at 4,300 million tons of bituminous coal with low volatiles and high ash averaging nearly 35%. The coal is non-coking and the deposit is not worked.

Rhodesia possesses coal reserves which are far in excess of the country's requirements for decades to come, and the Wankie coal is of such excellent quality that it is unlikely that any new major coalfields will be opened up. The export potential of Wankie coal is also limited by political and transport problems.

Apart from coal, hydro-electric power plays an important part in the overall production of energy but thermal power facilities for electricity production are also planned. A new power station at Wankie with an eventual output of 1,200 MW is to be started shortly and completion of the project in 1975 or 1976 should ensure the electric power requirements up to 1985 or 1990.

Swaziland

The Swaziland coal measures run for about 150 km from the north to the south of the country. The total present known reserves of saleable coal (without washing) amount to 207 million tons. Further geological exploration will undoubtedly increase these reserves.

The coal is found in two sub-divisions, i.e. the Middle Ecca series comprising 6 seams and the Upper Ecca series comprising one seam 9 m thick. The Middle Ecca coal is semi-anthracitic with a medium ash and low sulphur content. The coal can be up-graded by washing to give a 10% ash product with an acceptable yield. On the other hand, the Upper Ecca coal is high in ash and sulphur. Washing is not effective as the ash is intimately mixed with the coal substance.

A shallow drift mine is currently exploiting the Middle Ecca main seam and producing about 150,000 tons of saleable coal per annum. This coal is mainly used within the country for local industries and the railway to Lourenco Marques. Some coal is also exported to Kenya.

Although the coal demand for the railway may decline due to dieselisation, proposals for the construction of a large thermal power station to export power to South Africa are under consideration and could lead to a large increase in coal production. There are also potential export markets in Japan, Europe and East Africa.

Tanzania

Tanzania possesses fairly extensive coal resources and sporadic lignite occurrences have also been noted which apparently have no commercial value. The remoteness of the Tanzanian coalfields from potential markets and from the coast plus lack of communications, have so far prevented their exploitation on any scale, the annual estimated production for 1969 and 1970 being only 3,000 tons per annum, from the one small mine in the Songwe-Kiwira field. Construction of the Zambia-Tanzania railway will undoubtedly assist in the development of the country and the coalfields adjacent to this line could very well be developed.

In general, the coals in the workable seams of the Mchuchuma field average 2 m to 5 m thick and are equivalent to average good quality African coals with low sulphur content. Proximate analyses give 14% ash, 24% volatiles and calorific values of 12,800 btu/lb (7,100 kcal/kg). Total proved reserves of this field are estimated at approximately 190 million tons of which 60% is considered extractable.

In the Ngaka field four main seams have been discovered of varying thickness from 50 cm to 5 m. Proximate analyses give 12% to 18% ash and 24% to 30% volatiles, with calorific values averaging 12,000 btu/lb (6,670 kcal/kg). Proved reserves are approximately 100 million tons.

The Songwe-Kiwira coalfield has two workable seams with over 20 million tons proved reserves. The seams vary from 2 m to 2.5 m thick but locally range up to 6 m. Proximate analyses give 14% to 20% ash, 22% to 32% volatiles and calorific values of 10,500 to over 12,000 btu/lb (5,820 to 6,670 kcal/kg). The top seam has some coking properties.

The coals are typical of the Gondwana type which show a great deal of variation and high ash content, much of which is intimately associated with the organic constituents of the coal, so that washing is difficult.

Zaire

Coal is found in two coal basins, both of which lie in Katanga and they have high ash contents and high volatiles.

In the Luena basin, where mining has been in progress for some years, there are up to four coal seams from 1 m to 5 m thick. Proximate analyses of the Luena coals give averages of 20% ash, 34% volatiles and 6% to 8% moisture. With an ash content of 25%, the calorific value of the coal is approximately 9,000 btu/lb (5,000 kcal/kg). Total coal reserves of all classifications are estimated at 23 million tons.

Very large coal reserves are reported to exist in the Lukuga basin area where some mining has been carried out, and which lies approximately 20 km west of Albertville. There are five main seams of varying thickness from 30 cm to 2.4 m and the quality of the coal is very similar to that at Luena. Total reserves so far exposed have been estimated at 50 million tons but according to Belgian reports, the true figure is of the order of 750 million tons.

Despite the apparently large coal reserves, exploitation has been limited, the greatest output being achieved in 1959 when almost 250,000 tons of coal were mined. In recent years however, production has been increasing again, but it has only lately reached just over 100,000 tons per annum.

The country's GNP during the 1960's increased at a rate of 5.5% per annum whereas the increase in energy consumption was only 2.8% per annum. With a vast potential mineral wealth and enormous land area to be exploited, the current energy growth rate will probably be exceeded in the future but the lack of infrastructure and also industrial base within the country will restrict overall energy demands for some time to come.

Zambia

Zambia is very poorly endowed with fossil fuels, having no oil or natural gas, and coal reserves are small and of poor quality.

For several years now Zambia has been mining coal and in 1970 a production of 623,000 tons was achieved from Maamba collieries. This opencast project is the only operating coal mine in Zambia and it produces a high-sulphur coal which has to be washed. Reserves at Maamba are contained within two seams and, at a 6:1 stripping ratio, over 31 million tons of coal are available with an average ash content of 19.6%. The coal seams grade into a Carbonaceous shale in the hanging wall of the deposit and therefore the cut-off point is usually made on the ash content of the coal. Proximate analyses give 23.6% ash, 19% volatiles, 1.5% sulphur and the calorific value of the coal is approximately 10,600 btu/lb (5,900 kcal/kg).

Home production and imports supply a large but diminishing coal market, primarily in the Copperbelt. The reverberatory copper furnaces burn a large amount of coal, but plans are already afoot to use electric furnaces. Coal will undoubtedly continue to play a part within the primary energy field for some time to come, but hydro-electrical projects will possibly supplant coal in importance within the next few years.

EAST ASIA

East Asia's energy requirements are currently being supplied by oil (60%), solid fuels (16%), with natural gas, hydro and nuclear power sharing the remainder. The region is on balance a net importer of energy, consumption being more than twice the level of production. The region imports solid fuels and petroleum and exports natural gas.

Japan consumes 61% of the energy of the region but is not considered here among the developing countries. The estimated reserves and the production of coal and lignite in the main developing countries in the region are given in the following table.

COAL AND LIGNITE RESERVES OF EAST ASIA

Country	Date	Reserves 10^6 tons	Production 10^3 tons			Comments
			1968	1969	1970	
COAL						
Afghanistan	1965	85	125	136	-	
Burma	1960	21	9	8	12	
India	1970	80,900	70,813	75,411	73,698	
Indonesia	1962	845	176	191	172	
Japan	1961	19,248	46,568	44,690	39,694	
North Korea	-	-	20,400	22,200	24,000	
South Korea	1962	1,300	10,242	10,272	12,394	
Pakistan	1966	1,661	1,200	1,250	1,249	
Philippines	1970	125	32	53	42	
Taiwan	1973	260	-	-	-	
Thailand	-	-	-	-	-	No coal reported
North Vietnam) South Vietnam)	1952	1,000	3,000	3,000	3,000	
TOTAL	-	105,445	152,565	157,211	154,261	
LIGNITE						
Afghanistan	-	-	-	-	-	Lignite reserves not recorded
Burma	1951	265	-	-	-	
India	1966	2,063	4,126	4,188	3,545	
Indonesia	1951	2,700	-	-	-	
Japan	1955	1,733	335	251	197	
North Korea	-	-	4,500	4,900	5,700	Lignite reserves not recorded
South Korea	1962	5	-	-	-	
Pakistan	1966	280	-	-	-	
Philippines	1965	88	-	-	-	
Taiwan	-	-	-	-	-	
Thailand	1967	235	305	348	400	
North Vietnam) South Vietnam)	1952	-	-	-	-	No lignite found
TOTAL	-	7,369	9,266	9,687	9,842	

Notes: Sources: 1. U.N. Statistical Yearbook, 1972
2. International Coal Trade. U.S. Bureau of Mines

India

India has traditionally depended on non-commercial fuels such as firewood, dung and vegetable wastes for a considerable proportion of its energy supply; however, the position is slowly improving as commercial fuels now account for 50% of the total energy as compared with 23% in 1946. In 1971, firewood accounted for 37.7%, oil 23.5% and coal 19.4% of the total energy consumption.

Coal Reserves

The Geological Survey of India and the Indian Bureau of Mines recently reassessed the coal reserves of India as follows:-

	10^6 tons
Proved	21,000
Indicated	30,800
Inferred	29,100
	80,900

The breakdown into types was given as:-

	10^6 tons
Prime coking	5,651
Medium coking	9,433
Weakly coking	5,070
Non-coking	59,970
Tertiary	827
	80,951

The deposits occur mainly in the States of Bihar, West Bengal, Madhya and Orissa, with the coking coals in Bihar and West Bengal.

Coal Production

The Fourth Coal Plan aimed at 90 million tons by 1973/1974 but due to difficulties in the mines, most of which are still manually operated, production may not be more than 80 million tons. Output in 1971 was only 69.1 million tons of bituminous coal compared with 74.6 million tons in 1970; lignite production was constant at 3.7 million tons. Of this total production, 16.1 million tons was coking coal. The coal is used mainly for the iron and steel industry, railways, cement plants and domestic market. It is estimated that the demand in 1975 will be 93 million tons. By blending the bituminous coals, it is estimated that proved reserves will be adequate for supplying the iron and steel industry for 80 years at the present growth rate. Despite its own fuel shortages, India continues to export to neighbouring countries and has undertaken to supply up to 2 million tons of coal per annum to Bangladesh. However, in view of its own increasing demands and limited resources, India will not have a significant effect on the world international coal trade.

Indonesia

There are numerous deposits of coal, mainly located on the islands of Sumatra and Kalimantan. In-situ reserves were estimated at 845 million tons in 1962, but further geological exploration is expected to increase this figure. Current production of about 200,000 tons per annum is mainly from two mines, Bukit Assam near Palembang, and Ombilin near Padang in Sumatra. The Government is planning to re-organise the industry to increase output to satisfy domestic demands and if possible, an export market.

Korea (South)

This country has estimated coal reserves of 1,300 million tons consisting mainly of anthracite, of which 540 million tons are considered recoverable. The country is actively promoting the use of commercial fuels in order to prevent soil erosion resulting from cutting forests for firewood. Their coal production in 1971 was 12.8 million tons, and is scheduled to reach 16 million tons per annum by the end of the decade.

Some 75% of the production is used for household use, 10% generation of electricity and the remainder for miscellaneous industrial use and exports. Exports are mainly to Japan. Imports of bituminous coal and coke are about 17,000 and 65,000 tpa respectively. Domestic demands for coal are expected to increase in the future when the Pohang steel plant comes into operation.

Malaysia

Malaysia is a small importer of solid fuels (15,000 tpa) mainly anthracite from North Vietnam and coke from Japan, Netherlands and Taiwan.

Pakistan

Pakistan has coal deposits in the former provinces of Baluchistan, West Punjab, Sind and the N.W. Frontier. In 1968, the total reserves were estimated at 469 million tons of which 43.8 million tons were classified as "measured". The coal is lignitic in quality, having high moisture and volatile contents with ash contents ranging from 3% to 37%.

Production of coal is planned to increase from 1.2 million tons in 1970 to 4.8 million tons in 1975. The coal is used mainly for industrial purposes and for brick manufacture.

Bangladesh

The demand for coal in Bangladesh at present is met entirely from imports. However, large deposits of good quality, low sulphur, high volatile bituminous coal have been found at a depth of about 1,000 m in Jamalganj in the Bogra district. A scheme for the development and exploitation of this deposit is under consideration. Resources are tentatively estimated at about 1,500 million tons.

Philippines

Coal reserves are estimated at 125 million tons with a calorific value ranging between 4,660 and 8,100 kcal/kg.

In 1972, there were 11 mines producing coal, 9 of which were located on Cebu Island.

The quality of the coal is suitable for most industries and the low-grades can be blended with high grade varieties to obtain maximum utilization.

The Government is encouraging the development of coal for power generation, cement and sugar manufacture. Estimated requirements by 1976 are 2.4 million tons.

Taiwan

Coal reserves in Taiwan are estimated at 260 million tons with about 100 million tons of this capable of being mined economically.

Between 1965 and 1968, the annual output of coal averaged over 5 million tons but since has declined sharply due to rising costs and diminishing demand caused by a call for cleaner air. In 1972, production was 3.9 million tons from 162 mining companies. Of these about 100 are small operators with a combined output of only 10% of all coal mined in Taiwan. Productivity is low, averaging only 8 tons per man-month and the accident rate is high.

Taiwan has no known indigenous oil reserves, and in order to cope with the higher oil prices, the Government is planning to switch to coal for power generation. This will involve an expansion of coal production. Coal consuming industries, particularly the state-run power company, are being urged to enter into long-term supply contracts with the coal mining companies.

A new iron and steel plant is to be built at Kaohoiung which will require about 700,000 tpa of coal. Due to the low quality of the indigenous coals, it is assumed that a large proportion of the metallurgical coal requirements will have to be imported.

Thailand

Present indigenous solid fuel resources in Thailand are limited to the lignite fields at Mae Moh in the north and Krabi in the south. Mae Moh has 55 million tons of proved reserves (3,670 kcal/kg c.v.) while Krabi has proved reserves of 5 to 8 million tons (3,330 kcal/kg c.v.)

The existing mine at Mae Moh supplies a fertilizer plant and a 12.5 MW thermal power plant with about 200,000 tons of lignite per annum. Two 75 MW thermal units are being added and will require a further 5 million tons of lignite per annum when they are commissioned in 1977.

At Krabi, the mine supplies a 60 MW power plant.

CENTRAL AND SOUTH AMERICA

The known reserves of coal and lignite are small and production of solid fuels only represents 2.3% of the total regional production of energy.

The table below gives details of the estimated reserves and production of coal and lignite in the main developing countries in the region.

Argentina

Although coal reserves are known to exist in a number of provinces, only one deposit is being worked at Rio Turbio in the extreme south of the country. Production of saleable coal in 1972 was 675,000 tons. Apart from a small tonnage used locally, the coal produced is shipped to the industrialised areas near the River Plate where it is either blended with imported coking coal for steel production, or used in thermal power stations. In order to reduce coal imports, the Government plans to increase production to 3 million tons per annum by 1980.

Brazil

Next to Colombia, Brazil has the largest reserves of coal in Central or South America. Coal is being mined in three

COAL AND LIGNITE RESERVES OF CENTRAL AND SOUTH AMERICA

Country	Date	Reserves 10^6 tons	Production 10^3 tons			Comments
			1968	1969	1970	
COAL						
Argentina	1966	450	472	522	616	
Brazil	1966	10,675	2,364	2,437	2;361	
Chile	1966	218	1,417	1,491	1,377	
Colombia	-	12,500	3,100	3,317	3,317	
Mexico	1966	3,466	1,558	1,500	1,800	
Peru	1966	2,334	161	162	156	
Venezuela	1969	150	-	-	40	
TOTAL	-	29,793	9,072	9,429	9,667	
LIGNITE						
Argentina	-	-	-	-	-	Small deposits reported
Brazil	-	-	-	-	-	Lignite reserves not recorded
Chile	1966	5,365	57	68	N.A.	
Colombia	-	-	-	-	-	
Mexico	-	-	-	-	-	
Peru	1966	4,630	-	-	-	
Venezuela	-	-	-	-	-	
TOTAL	-	9,995	57	68	N.A.	

Notes: Sources: 1. U.N. Statistical Yearbook, 1972
2. International Coal Trade. U.S. Bureau of Mines

provinces - Santa Catarina, Rio Grande de Sul and Parana. Santa Catarina is the only producer of metallurgical coal, but it is costly to mine and contains 18% to 33% ash and 1.8% sulphur. Recovery of clean coal is only about 42% of the run-of-mine production.

In 1972, total production amounted to 5,920,000 tons of which 2,490,000 tons was saleable. Santa Catarina produced 57% of this total. At present, Brazil imports more than 43% of its coal requirements, most of which are used by its rapidly expanding iron and steel industry.

<u>Chile</u>

Although known reserves of coal in Chile are small, there are substantial undeveloped deposits of lignite. Production of coal in 1971 was 1,620,000 tons, mainly from the Lota-Schwager mine which was nationalised during that year.

The demand for steam coal for power generation is decreasing mainly because of increased power from hydro-electric plants. The steel industry is the largest coal consumer in Chile and blends domestic coal with imported coal for the manufacture of coke.

<u>Colombia</u>

Colombia holds about 80% of South America's coal reserves with a range in quality from sub-bituminous to anthracite. The most important deposits are situated in the Departments of Cundinamarca, Boyaca, Santander, Norte del Cauca, Caldos and Risaralda. The Cerrejon deposits are reported to contain reserves ranging from 80 to 200 million tons.

Current production of coal (about 3.3 million tons annually) is adequate for all domestic needs, including the iron and steel and electric power industries. The Government is seeking to expand the coal industry but there are problems of costs and transportation. However, the deposits at El Carrejon are located within reasonable distance from a railway line to the Caribbean port of Cartagena.

Mexico

The reserves of coal in Mexico, estimated at 3,460 million tons are located in thin seams which are expensive to mine. Coal production for 1972 amounted to 3.3 million tons which was mainly used for coke manufacture for the iron and steel industry. The internal demand for steel is expected to rise to 8 million tons by 1980 and this will necessitate a large increase in coke production. Although a higher indigenous production of coal is planned, it is expected that imports of coking coal will also increase, mainly from the U.S.A.

Peru

There are numerous coal deposits in Peru, but they have not been developed extensively. Proved reserves of anthracite are estimated at 20 to 30 million tons and bituminous and sub-bituminous coals at about 2,000 million tons. Some of the bituminous reserves are of moderate coking quality.

Production of anthracite and bituminous coal recently has been reported at about 8,000 and 170,000 tons per annum respectively. Most of the current output is obtained from the Goyarisquisga mine in the Department of Pasco.

The feasibility of developing a large mining complex in the Oyon area of the Department of Lima is being considered with a view to the expansion of the steel plant at Chimbote. Currently, Peru imports a large part of its coke requirements, most of it from the U.S.A.

Venezuela

Although there are reports of sizeable resources of coal in Venezuela, current production of coal is on a very small scale. Output in 1970 was about 40,000 tons, mainly from Lobatera mine. In the past, the mines have operated sporadically, depending on market conditions. The high cost of mining and quality considerations have discouraged the Government-owned steel industry from using locally produced coal. Thus, coke has to be purchased in the foreign market, much of it from the U.S.A.

MIDDLE EAST

The estimated coal and lignite reserves of the Middle East are minute by world standards, only Turkey and Iran having substantial deposits. Owing to the vast resources of oil, the region is a net exporter of energy.

The table below gives details of the estimated coal reserves and production for Iran and Turkey.

Iran

The energy requirements of Iran are currently being met by oil (60%), natural gas (16%), coal (2%) and the balance by hydro-electric power and non-commercial fuels (wood, charcoal and animal products). In the Fifth Plan (1973-78) the consumption of coal is planned to increase from 227,000 tons to 783,000 tons per annum.

COAL AND LIGNITE RESERVES OF MIDDLE EAST

Country	Date	Reserves 10^6 tons	Production 10^3 tons		
			1968	1969	1970
COAL					
Iran	1961	1,000	297	490	530
Turkey	1957	1,335	4,769	5,089	4,953
TOTAL	-	2,335	5,066	5,579	5,483
LIGNITE					
Iran	-	-	-	-	-
Turkey	1972	4,160	4,101	4,356	4,540
TOTAL	-	4,160	4,101	4,356	4,540

Notes: Sources: 1. U.N. Statistical Yearbook, 1972

2. International Coal Trade. U.S. Bureau of Mines.

Reserves of coal were estimated at 1,000 million tons in 1961. The most important coal deposits are at Kerman, the Alborz mountains and Shahrud.

Turkey

The bituminous coalfields of Turkey are located at Zonguldak, about 300 miles east of Istanbul. They extend from Erejli to Asmara along the Black Sea coast for a distance of over 60 miles. Prospecting is still in progress to determine actual extent of the field. Current known reserves were estimated at about 1,400 million tons in 1967. The coal is high in ash and, after cleaning, most of the Zonguldak coals are suitable for use in the manufacture of metallurgical coke. In 1971, the run-of-mine output was 7,850,000 tons.

The production of lignite in Turkey is of great importance especially for domestic use. Production has doubled in the past decade and further expansion is expected as newly-explored deposits are developed. Measured reserves are said to be over 4,000 million tons. Most of the lignite lies in western Turkey, although in recent years large deposits have been discovered in the eastern part of the country. These are currently being developed for power generation at Elbistan. Most of the lignite seams are thick and lie at shallow depths, favouring surface mining.

Owing to the shortage of other fossil fuels, Turkey is dependent largely on indigenous production of coal and lignite for domestic and industrial purposes. Some years ago, Turkey exported bituminous coal from Zonguldak, but now all the output is required for internal use.

ANNEX 4

METHODS OF EXTRACTION

PRESENT METHODS

Currently, coal is extracted by one of the following basic methods:-

(i) Surface mining.

(ii) Auger mining.

(iii) Underground mining, including:-

(a) Room-and-pillar

(b) Longwall

(c) Hydraulic

(iv) Underground gasification.

Selection of Method of Mining

The selection of the method of mining is of prime importance, affecting as it does safety, the environment and the cost of production. When planning new mines the following factors must be carefully assessed in order to select the best method of mining:-

(i) Potential market requirements in terms of tonnages, quality and price.

(ii) Availability of capital, labour and supporting services.

(iii) Transportation facilities and infrastructure required.

(iv) Environmental constraints.

(v) Geological constraints including:-

(a) The depth, inclination and thickness of seam(s) to be mined.

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(b) Nature of strata above and below the seam(s).

(c) The reserves in-situ and the percentage of extraction to be achieved.

(d) The quality of the coal in-situ and the "washability" characteristics of the run-of-mine coal.

(e) The geological structure of the area, ground water, soil and rock mechanics.

(f) The liability of the seam to spontaneous combustion, outburst, water make, dust and gas emission.

SURFACE MINING

This system of mining, although sometimes subject to difficult, but not necessarily intractable, problems in its land use aspect, offers important operational and cost advantages compared with underground mining where the exploitable coal reserves are accessible to recovery by opencast mining methods (strip mining).

In opencasting, large volumes of ground overlying the coal seam (overburden) require removal per unit of coal produced. The viability of the system derives from the development of large, excavation equipment giving low excavation costs and from improvements in drilling and blasting techniques for breaking and preparing hard overburden strata, where necessary, to a suitable degree of fragmentation for loading. The main excavation equipment is specialised and manufactured by a relatively small number of companies and it is frequently designed or adapted by the manufacturer to suit the conditions of a particular mine. In general, the

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largest equipment commensurate with production requirements and geological factors gives the lowest operating costs, although in the case of very large units the high cost of downtime, standby provision, capacity of the electricity supply system, etc. modify the trend.

Productivity and Costs

The productivity of surface mining is high, although this ranges widely according to systems and conditions from a low of about 12 tons per manshift to a high of 200 tons in some of the larger mines. This, along with the necessary high degree of mechanisation, results in a high capital cost per job opportunity. However, as mining is a primary producer, low production cost can be essential to other aspects of national production, e.g. electrical energy, heat. An important consideration of special significance in some industrialised areas, is that skilled labour may be more readily recruited in surface mining than in underground mining.

The cost of equipping and installing an opencast mine is likely to be less than half that of an underground mine of the same output and the cost and the time for development is also substantially less than for a deep shaft mine (although in the case of shallow adit or drift mines if compared with a moderately deep surface development this might not be so). Also greater productivity, concentration of operations, simplified management, better working environment, greater safety, etc. are important advantages.

As mining projects tend to be unique entities with costs governed by geological factors, locality, etc., etc., it is not possible to establish standard investment costs which would be generally applicable, although of course in all cases the final production cost has to be such as to provide adequate return within the prevailing selling price ceiling. The scale effect is very pronounced and for that reason lignite mines in particular are becoming very large, e.g. 50 million tons per annum. Hard coal strip mines are much smaller for geological and environmental reasons (e.g. up to 6.5 million tons per annum in U.S.A.).

The geographical location can of course add substantially to the costs of establishing a mine in a remote area.

For most developing countries, mining projects involve a substantial foreign exchange commitment in firstly, the initial purchase of the machine and secondly the continuing supply of maintenance spares. In a typical surface mine development, the cost of equipment may amount to 60% to 70% of the total investment and the annual spares cost possibly 20% of total working costs.

Working Limits

The working limits for surface mining are based on an assessment of the depth to which mining can extend before becoming uneconomic per se or relative to the alternative of underground mining; this is known as the "cut-off stripping ratio" i.e. cubic metres of overburden removed per ton of product. This ratio varies widely from about 4:1 to more than 20:1 according to the

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type of equipment used, nature of overburden, cost of underground mining alternatives, selling price, etc.

Both the investment cost and the operating cost are very roughly proportional to the quantity of material moved, i.e. the stripping ratio plus one.

The depth of working is limited to about 60 m in the case of draglines and stripping shovels. For greater depths direct casting is not possible because of the width of the excavation and the spoil has either to be transported across the pit either by rehandling or by conveyor bridges (which are confined to the simple geometry of lignite mines) or to be transported round the pit by trains, dump trucks or conveyors. These systems are, of course, more expensive but they extend the depth range to 300 m or more. As the mine becomes deeper other problems increase, e.g. slope stability, ground water, area of pit, but there is no technical limit to ultimate depth. (800 m has been reached in metal mines.)

Methods of Excavation

The methods of excavation vary for differing ground conditions and output demands; in general high capacity equipment is used for overburden removal and the coal seam is recovered by smaller and more selective equipment. The mining system may be continuous, as represented by multi-bucket excavators (bucket wheel and bucket chain) and the conveyor belt, or discontinuous as in the use of shovels, draglines, scrapers, dump trucks, etc.

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The main excavation systems in current use are as follows:-

(i) <u>Tractor Scrapers and Dozers</u>

These machines, with the aid of ancillary equipment for ground preparation, load assistance, etc., excavate, transport and dump the overburden or coal in a single cycle of operation. They are most suitable for use in short-life, shallow deposits with soft to medium-hard strata. The equipment has the benefit of mobility, and is lower in initial capital cost than other methods, but is usually higher in operating costs and in man-power. Scrapers vary in size up to a capacity of 90 cubic metres although 20 to 50 cubic metres are the most popular sizes.

(ii) <u>Stripping Draglines and Shovels</u>

This system is based on the use of long-reach machines capable of swinging the loaded excavator bucket across the width of the pit to discharge the overburden spoil clear of the coal, which is thus progressively exposed and then loaded from the base of the pit. (Direct casting system.) The system derives its economies from the elimination of subsidiary transport for spoil and it is very effective, where applicable. The largest dragline at present in operation has a 95 m boom with a 168 cubic metre capacity bucket, service weight 12,700 tons and connected load of 36,000 kW. Rather smaller sizes are, however, more common.

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Stripping shovels, which have a more positive digging action than draglines, are more productive under suitable conditions and can dig tougher ground. They are also used in direct-casting systems. Extended booms give the necessary radius of swing for disposing spoil behind the coal working area and they stand on the top of seam instead of on a surface or sub-surface bench as is the case with draglines. The stripping shovel however involves a higher investment cost due to structural factors and has operational limitations in that it is relatively immobile and inflexible. It is less widely used. The largest machine reported in service has a 138 cubic metre dipper bucket on a 65-m long boom with an installed load of 22,500 kW.

Smaller draglines are frequently used on the spoil bank side of the mine to rehandle spoil and increase the disposal range of the main excavator as well as to assist in spoil bank levelling for land rehabilitation.

The coal seam is normally mined by separate equipment - usually face shovels (mechanical or hydraulic) or wheel loaders. Coal transport is generally by dump truck. Overburden removal is closely co-ordinated with coal production to maintain exposed reserves as a safety margin against geological anomolies and mechanical failure of equipment. Coal-loading shovels vary in bucket capacity from about 4 cubic metres to possibly 10 cubic metres and load to trucks of up to 200 tons capacity, the optimum size being a function of output and haul distance

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relative to costs. Wheel loaders range in capacity from 2 to 18 cubic metres.

(iii) Shovels and Dump Trucks

This excavation and transport system for overburden removal has higher cost elements compared with dragline operation because of the need to remove overburden debris by heavy duty off-highway type dump trucks in place of direct casting, but it can be applicable where there is hard overburden or multiple coal seams involving deep strips for the successive recovery of the seams. Currently in the U.K. depths of 100 m are being worked by this system. Face shovel sizes range up to 30 cubic metres and truck capacities under design are up to 400 tons. The excavation and transport system requires to be matched for efficient operation.

(iv) Multi-Bucket Excavators and Belt Conveyor Transport

This continuous mining system is suitable for weakly consolidated alluvial overburden and to large areas of relatively flat and thick seams although its application is extending into harder formations.

The system can be designed to very high capacities with low unit excavation costs. The largest bucket-wheel excavators (BWE) in service have output capacities of 100,000 cubic metres (in-situ) per day with a height reach of 50 m and a depth reach of 25 m. The operating weight is 7,400 tons.

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Bucket chain excavators, which preceded the bucket-wheel excavator, are also used in the above mining system, but have a more limited application, being unselective in loading and suitable for weak ground only. Power and maintenance costs are higher than that of the BWE under similar operational conditions, although in some field conditions the system is still applicable.

The conveying system for the BWE operation may be a round-the-pit belt system or a form of direct disposal via conveyor bridge; a mobile spreader; or an extended conveyor boom integral with the excavator. In the round-the-pit system the spoil is conveyed along the mining bench, across the end or through a pivot point of the mine benches and then to a spoil bank behind the working benches for disposal through a mobile spreader. The system used may be governed by the need for selective mining, e.g. handling coal and spoil from one bench, and by the number of benches in operation. For the largest installations conveying capacities reach 20,000 cubic metres per hour on 3 m wide belts at belt speed of 5.4 m/s. The conveyors are slewable sideways to enable the system to be advanced as the benches advance.

AUGER MINING

In hilly terrain, when the rising ground above the coal makes a wall too high for economic surface methods, auger mining can be used to extract some further coal from the seam after stripping finishes. Large augers with cutting heads up to 2 m in diameter, bore closely-spaced holes into the coal seam, drawing out the coal from as much as 70 m inside the hill. The system, although cost effective, may be criticised in that it effectively bars the further extension of surface operations where changes in economic factors permit and also causes undesirable caving.

UNDERGROUND MINING

Room-and-Pillar System
("Bord-and-Pillar", "Pillar-and-Stall")

In this system, the seam is extracted by first driving headings in the coal, variously termed "rooms", "bords" or "stalls" and, in certain circumstances where conditions permit, subsequently extracting a large proportion of the pillars formed between these drivages, thereby causing the roof to cave.

Three degrees of mechanisation are employed, i.e.:-

(i) The simplest form uses coal cutters, drills and explosives, the broken coal being hand-loaded into tubs or cars delivered into the rooms. Except in developing countries, this type of mechanisation is being replaced by more sophisticated equipment.

(ii) The second form is characterised by the substitution of hand-loading by mechanical loading using gathering-arm loaders and the use of electric or diesel-driven shuttle cars or chain conveyors for face transport.

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(iii) In the last decade, continuous mining machines have been employed to cut and load the coal in one operation. Coal transport away from the face is by shuttle car, chain conveyor or extensible and mobile belt conveyors.

Compared with longwall mining, the room-and-pillar system has the advantage of lower operating cost and capital investment, higher productivity and flexibility in disturbed geological conditions. On the other hand, the percentage of coal recovered, especially when the pillars are not extracted, is lower and progressively decreases as the depth increases. The workings are more difficult to ventilate and at great depths the effects of pressure are accentuated so that "creep" and "thrust" may seriously damage and restrict the roadways.

<u>Longwall Mining</u>

In this system, coal is extracted by a long, straight face ("wall") which can be up to 350 m in length and which either advances from the mine entrance towards the boundary of the mining area, or retreats from the boundary towards the mine entrance. In the advancing system, the roadways giving access to the face are driven simultaneously with the advance of the face and are subject to damage by strata movement in the caved area. To reduce this damage, stone packs are built or pillars of coal left along the roadway sides. With the retreating system, all roadways serving the face are driven before the face starts production. These roadways are then abandoned after the face has passed. The

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longwall retreating system has advantages over the advancing system because geological problems are detected before production and the access roadways retain their cross-sectional area for the duration of their working lives. It also has substantial advantages in seams liable to spontaneous combustion. However, it necessitates keeping the development work to programme and earlier investment in that work.

Longwall operations can be mechanised in two ways:-

(i) The simplest form employs coal cutters, drills and explosives; the broken coal being hand-loaded either into tubs or on to a chain or belt conveyor running along the coal face.

(ii) In recent years, power-loading machines, such as the shearer-loader, the coal plough and the trepanner, have been introduced into many mines to cut and load the coal without the use of explosives. Control of the roof along the working face is provided either by props and bars or by self-advancing hydraulic supports. In countries where labour costs are high, fully automated longwall units may be worked, whereby all operations along the face such as the movement of the power-loader, the advance of the conveyor and supports are automatically controlled from one of the access roadways.

Compared with the room-and-pillar system, the main advantages of longwall mining are the high percentage of extraction of the available reserves particularly as depth increases, the ability to work thin seams and the simplicity of the ventilation

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and supply systems. However it invariably causes surface subsidence.

HYDRAULIC MINING

In hydraulic mining, coal is broken by a high pressure water jet and the broken coal is transported by water to the mine surface where it is separated, cleaned and dried, the water being recirculated. The method is employed in a number of countries such as Canada, China, Czechoslovakia and Poland where conditions are favourable to its application. Coal seams extracted by this method should be moderately thick, friable and have a gradient sufficient to cause gravity flow of the coal/water mixture. The strata adjacent to the seam should not disintegrate under the action of water. The main advantages of the method in comparison with conventional underground mining are a significant decrease in dust and a reduced fire hazard. On the other hand, the consumption of electric power is high and coal losses are heavy.

UNDERGROUND GASIFICATION OF COAL

The essence of this technique is that coal in-situ is converted into a combustible gas which is pumped to the surface for use. The process is intended to eliminate the onerous conditions associated with conventional underground methods. The coal is ignited and converted into gaseous products underground as a result of thermal and chemical reactions. There are two methods of applying the technique; the first involves the driving of a network of tunnels by miners prior to the gasification of the coal, while the second technique requires the drilling of boreholes from the surface which are then inter-connected to enable

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air to be pumped to the combustion zone and the gasified products recovered.

For successful gasification, the coal seams should not be geologically disturbed, the rock strata should be compact with low gas permeability and the water inflow should be small. For economic reasons, the plant utilising the gas should be located near the coal deposits intended for gasification. Generally, the technique is applied to low-grade deposits which cannot be mined economically by conventional methods.

Although the technique has been tried in many countries, only the U.S.S.R. has developed the process on an industrial scale.

EXPLORATION

Adequate geological investigation of deposits is an essential pre-requisite for resources planning, if the best use is to be made of available coal reserves. However, it is seldom possible because of time and cost considerations to complete the investigation of a field before mining can be planned. Scout drilling is used to locate favourable areas and effort is then concentrated so that production can commence as soon as possible - and a positive cash flow established.

Mining is an extractive industry and therefore requires a continuing upgrading and replacement of reserves.

The extent of exploration is also governed by the investment risk. In the case of a high investment dependent upon a single mine, e.g. a power station, a high level of assurance would be required that the mineable reserves would last the life of the plant and that mining costs could be accurately predicted for the life of the project.

The first stage of a minerals study would involve the assessment of available information in order to locate the areas which are geologically most favourable. The methods involved in this phase may include aerial survey, air-borne geophysics and ground reconnaisance, test pitting, etc., if the area has not been previously mapped. The purpose of this phase is to delineate search areas.

It is only when this stage has been reached that the more costly investment by drilling is undertaken. Generally, core drilling is practised in which a core of seam is recovered for study. Open-hole drilling (non-coring) is practised in some circumstances where the lesser accuracy of the system is not critical and the cost and time savings are relevant. Where the sequence of strata is sufficiently well established, it is common to open-hole drill through the non-coal zones and then reserve the slower and higher cost coring operation for the coal seam and adjacent strata. Borehole survey techniques are also used which by geophysical testing can define changes in strata, ash percentage in coal, permiability, etc., as a supplementary check on results.

The cost of drilling varies according to type of strata, size of project, on-site cost of equipment, etc. To the basic cost of drilling must also be added the cost of geological control,

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assaying, transport, etc. A recent cost of exploring a shallow stratefied deposit averaged $35/metre drilled, but each project has to be costed on merit. The borehole density required for mine design depends on the geological conditions but for surface mining a drilling grid of 100 m and a depth of 100 m is typical.

Hydrological and rock mechanic studies are also likely to be required for project studies of surface mines, particularly the deeper ones; also soil studies for future land reclamation planning.

ANNEX 6

SUMMARY OF JAPANESE COKING COAL CONTRACTS - 1971

Source	Period	Total Quantity 10^6 LT	Quantity 1971 10^6 LT	Specification: Total Moisture %	Ash %	Volatiles %	Sulphur %	Swelling Index	Maximum Size in	Contract price for 1971 US$ per LT fob trimmed
Australia										
South Bulli	1969-78	13.3	1.4	7	10.3	21.4	0.4	5-7	2	15.6[illegible]
Coal Cliff	1967-77	12.4	1.3	7	10.3	21.0	0.4	5-7	2	14.[illegible]
Huntley	1971-76	1.0	0.2	7	10.3	28	0.55	7-8.5	0.5	14.[illegible]
Dombarton	1969-77	2.5	0.2	7	14.0	21-25	0.55	7.5-8.5	2	11.[illegible]
Wollondilly	1969-74	14.6	3.0	7	8.5	28	0.45	5	2	13.476
Moura	1963-78	54.4	4.3	8	8	29-32	0.55	6-8	1.25	12.9[illegible]
Blackwater	1968-77	27.8	2.9	8	8.3	25-27	0.5	5.5-6.5	1.25	10.67[illegible]
Goonyella	1971-84	50.5	2.5	8	7.3	25-27	0.65	6-8	2	13.2[illegible]
Peak Downs	1972-84	34.5	-	8	8.3	20-22	0.65	6-8	2	13.2[illegible]6
South Blackwater	1970-85	21.3	1.3	8	7.3	27-29	0.7	5-7	1.5	13.4[illegible]
Liddell	1969-74	1.3	0.3	7	8.5	37.5	0.6	5	2	11.[illegible]
Abersea	1969-74	0.7	0.1	7	8.5	37.5	0.8	4	2	11.07[illegible]
Newdell	1969-74	8.7	1.8	7	8.5	37.5	0.6	5	2	11.[illegible]
Newstan	1969-74	3.0	0.6	7	8.5	35-36	0.6	6	2	11.[illegible]
Big Ben	1969-74	7.5	1.5	7	9.5	35	0.64	5.5	1.25	10.[illegible]7
Daiyon	1969-74	4.7	1.0	7	9	35-37	0.75	4-5	2	10.[illegible]
Rathluba	1970-74	0.8	0.2	7	8.5	36-38	0.85	4-5	2	10.[illegible]4
Canada										
Balmer	1970-85	77.8	4.4	6	9.5	19-22	0.4	6-8	1.5	12.8[illegible]
Vicary Creek	1967-82	18.5	1.1	5	9.5	20-23	0.6	6	2	10.850
Luscar	1970-85	15.0	1.0	6	8.5	24-26	0.37	5-7	1.5	1[illegible].680
Smoky River	1970-85	29.5	1.5	6	6.3	17-20	0.55	7-9	1.5	18.0[illegible]0
Smoky River No. 9	1974-89	45.8	-	6	6.3	17-20	0.55	7-9	1.5	2[illegible].[illegible]00
Fording River	1972-87	45.0	-	6	8	21-24	0.45	5-7	1.5	1[illegible].[illegible]0
Stewart	1968-78	1.3	0.2	6	9	16-17	0.6	6-8	-	15.080
Poland										
Composite	1974-84	25.0	-	7	5.5	26-28	0.75	8-9	2	25.000*
South Africa										
Witbank composite	1972-86	27.4	-	7	7	32-35	0.7	2.5	1.25	11.[illegible]
U.S.A.										
Itmann	1967-83	65.6	3.9	4.5	5.5	16-19	0.8	7-9	2	20.8[illegible]*
Keystone	1967-81	27.2	2.2	4	5.5	16-18	0.8	8-9	2	[illegible]*
Beatrice	1967-80	48.4	3.4	4	5.5	16-18	0.8	8-9	2	[illegible]*
Pittston	1969-79	113.8	10	5	6	28.5	0.65	7-9	2	19.[illegible]
B.S. Blend	1969-79	10.5	1.1	5	6	29-30	0.95	7-9	2	18.8[illegible]0
Virginia	1970-85	27	1.8	4	5.5	17-18	0.67	8-9	2	21.950*
Pocahontas No. 4	1972-87	10.8	-	5	6.5	21	0.85	9	2	Negotiated Annually
Lancashire	1970-85	9.6	0.4	5	6	30-33	1.0	7-9	2.25	16.850
Kellerman	1970-82	10.2	0.9	5	8	28	0.8	7-8	2	19.680
Swanee	1971-81	6.5	0.7	7	6.5	40	1.0	4.5-5	2	17.880
Sunnyside										
India										
W. Bengal	Small shipments un-washed coal			6-25	12-15	24-36	0.3-0.8	1-7	Various	11.70 to 12.50
USSR										
Siberia	1969-75	2.9	N.A	6-8	8.5-9	14-42	0.5-0.6	N.A	N.A	12.80 to 16.70

* cif prices

Source: Imported Coking Coal Manual, Tex, 1971

ANNEX 5

HISTORIC COAL PRICES

REPORTED COAL PRICES 1955-72 AND SOURCES

Year	1 U.S.A. $/ton	2 U.K. £/ton	3 Canada C.$/ton	4 Australia A.$/ton	5 W.Germany DM/ton
1972	-	6.48	-	-	-
1971	7.78	6.38	6.70	4.22	-
1970	6.89	5.74	5.26	3.68	82.7
1969	5.49	5.03	4.82	3.61	68.3
1968	5.14	4.82	5.00	3.40	66.8
1967	5.08	4.84	5.16	-	62.5
1966	4.99	4.94	7.44	-	63.5
1965	4.88	4.50	6.74	-	64.0
1964	4.90	4.51	6.62	-	62.5
1963	4.83	4.54	7.02	-	61.0
1962	4.93	4.51	6.88	-	59.0
1961	5.04	4.46	6.90	-	59.5
1960	5.16	4.22	7.06	-	67.0
1959	5.25	4.10	7.16	-	69.0
1958	5.35	4.18	7.00	-	73.0
1957	5.59	4.03	-	-	72.5
1956	5.30	3.78	-	-	67.0
1955	4.95	3.34	-	-	62.0

Sources:
1. "FOB Mines" average figures from "bituminous coal data". Believed to mean average price loaded on rail (that is the FOR price).
2. "Average Pithead" (not loaded) prices from NCB Annual Reports.
3. Figures calculated from "Production" and "Value at Mines" from "Canada Coal Mines" 1972. Figure for 1967 and later exclude subvention payments and other assistance.
4. Figures calculated from "Production" and "Value" from "Australian Mineral Industry Review" 1970 and 1971.
5. Average figure for power station coal delivered to Dusseldorf from "Eurostat 1-2 1973" and "Statistik der Kohlen Wirtschaft e V" 1974.

ANNEX 6

SUMMARY OF JAPANESE COKING COAL CONTRACTS - 1971

Source	Period	Total Quantity 10^6 LT	Quantity 1971 10^6 LT	Specification: Total Moisture %	Ash %	Volatiles %	Sulphur %	Swelling Index	Maximum Size in	Contract Price for 1971 US$ per LT fob trimmed
Australia										
South Bulli	1969-78	13.3	1.4	7	10.3	21.4	0.4	5-7	2	15.6[illegible]
Coal Cliff	1967-77	12.4	1.3	7	10.3	21.0	0.4	5-7	2	14.6[illegible]
Huntley	1971-76	1.0	0.2	7	10.3	28	0.55	7-8.5	0.5	14.6[illegible]
Dombarton	1969-77	2.3	0.2	7	14.0	21-25	0.55	7.5-8.5	2	11.[illegible]
Wollondilly	1969-74	14.6	3.0	7	8.5	28	0.45	5	2	13.470
Moura	1965-78	54.4	4.3	8	8	29-32	0.35	6-8	1.25	12.5[illegible]
Blackwater	1968-77	27.8	2.9	8	8.3	25-27	0.5	5.5-6.5	1.25	10.6[illegible]
Goonyella	1971-84	50.5	2.5	8	7.3	25-27	0.65	6-8	2	13.[illegible]
Peak Downs	1972-84	34.5	-	8	8.3	20-22	0.65	6-8	2	12.2[illegible]0
South Blackwater	1970-85	21.3	1.3	8	7.3	27-29	0.7	5-7	1.5	13.[illegible]6
Liddell	1969-74	1.3	0.3	7	8.5	37.5	0.6	5	2	11.3[illegible]
Abersea	1969-74	0.7	0.1	7	8.5	37.5	0.8	4	2	11.074
Newdell	1969-74	8.7	1.8	7	8.5	37.5	0.6	5	2	11.5[illegible]
Newstan	1969-74	3.0	0.6	7	8.5	35-36	0.6	6	2	11.3[illegible]6
Big Ben	1969-74	7.5	1.5	7	9.5	35	0.64	5.5	1.25	10.657
Daiyon	1969-74	4.7	1.0	7	9	35-37	0.75	4-5	2	10.656
Rathluba	1970-74	0.8	0.2	7	8.5	36-38	0.85	4-5	2	10.634
Canada										
Balmer	1970-85	77.8	4.4	6	9.5	19-22	0.4	6-8	1.5	12.850
Vicary Creek	1967-82	18.5	1.1	5	9.5	20-23	0.6	6	2	10.850
Luscar	1970-85	15.0	1.0	6	8.5	24-26	0.37	5-7	1.5	13.680
Smoky River	1970-85	29.5	1.5	6	6.3	17-20	0.55	7-9	1.5	18.0[illegible]
Smoky River No. 9	1974-89	43.8	-	6	6.3	17-20	0.55	7-9	1.5	21.800
Fording River	1972-87	45.0	-	6	8	21-24	0.45	5-7	1.5	12.850
Stewart	1968-78	1.3	0.2	6	9	16-17	0.6	6-8	-	15.080
Poland										
Composite	1974-84	25.0	-	7	5.5	26-28	0.75	8-9	2	25.000*
South Africa										
Witbank composite	1972-86	27.4	-	7	7	32-35	0.7	2.5	1.25	11.[illegible]
U.S.A.										
Itmann	1967-83	65.6	3.9	4.5	5.5	16-19	0.8	7-9	2	20.8[illegible]*
Keystone	1967-81	27.2	2.2	4	5.5	16-18	0.8	8-9	2	21.[illegible]*
Beatrice	1967-80	48.4	3.4	4	5.5	16-18	0.8	8-9	2	21.[illegible]*
Pittston	1969-79	113.8	10	5	6	28.5	0.65	7-9	2	19.[illegible]
B.S. Blend	1969-79	10.5	1.1	5	6	29-30	0.95	7-9	2	18.800
Virginia Pocahontas No. 4	1970-85	27	1.8	4	5.5	17-18	0.67	8-9	2	21.950*
Lancashire	1972-87	10.8	-	5	6.5	21	0.85	9	2	Negotiated Annually
Kellerman	1970-85	9.6	0.4	5	6	30-33	1.0	7-9	2.25	16.8[illegible]
Swanee	1970-82	10.2	0.9	5	8	28	0.8	7-8	2	19.680
Sunnyside	1971-81	6.5	0.7	7	6.5	40	1.0	4.5-5	2	17.880
India										
W. Bengal	Small shipments un-washed coal			6-25	12-15	24-36	0.3-0.8	1-7	Various	11.70 to 12.50
USSR										
Siberia	1969-75	2.9	N.A	6-8	8.5-9	14-42	0.5-0.6	N.A	N.A	12.80 to 16.70

* cif prices

Source: Imported Coking Coal Manual, Tex, 1971

ANNEX 6

SUMMARY OF JAPANESE COKING COAL CONTRACTS - 1971

Source	Period	Total Quantity 10^6 LT	Quantity 1971 10^6 LT	Specification: Total Moisture %	Ash %	Volatiles %	Sulphur %	Swelling Index	Maximum Size in	Contract Price for 1971 US$ per LT fob trimmed
Australia										
South Bulli	1969-78	13.3	1.4	7	10.3	21.4	0.4	5-7	2	15.643
Coal Cliff	1967-77	12.4	1.3	7	10.3	21.0	0.4	5-7	2	14.643
Huntley	1971-76	1.0	0.2	7	10.3	28	0.55	7-8.5	0.5	14.638
Dombarton	1969-77	2.5	0.2	7	14.0	21-25	0.55	7.5-8.5	2	11.136
Wollondilly	1969-74	14.6	3.0	7	8.5	28	0.45	5	2	13.470
Moura	1965-78	54.4	4.3	7	8	29-32	0.55	6-8	1.25	12.994
Blackwater	1968-77	27.8	2.9	8	8.3	25-27	0.5	5.5-6.5	1.25	10.674
Goonyella	1971-84	50.5	2.5	8	7.3	25-27	0.65	6-8	2	13.200
Peak Downs	1972-84	34.5	-	8	8.3	20-22	0.65	6-8	2	13.200
South Blackwater	1970-85	21.3	1.3	8	7.3	27-29	0.7	5-7	1.5	13.436
Liddell	1969-74	1.3	0.3	7	8.5	37.5	0.6	5	2	11.366
Abersea	1969-74	0.7	0.1	7	8.5	37.5	0.8	4	2	11.074
Newdell	1969-74	8.7	1.8	7	8.5	37.5	0.6	5	2	11.366
Newstan	1969-74	3.0	0.6	7	8.5	35-36	0.6	6	2	11.306
Big Ben	1969-74	7.5	1.5	7	9.5	35	0.64	5.5	1.25	10.657
Daiyon	1969-74	4.7	1.0	7	9	35-37	0.75	4-5	2	10.656
Rathluba	1970-74	0.8	0.2	7	8.5	36-38	0.85	4-5	2	10.634
Canada										
Balmer	1970-85	77.8	4.4	6	9.5	19-22	0.4	6-8	1.5	12.850
Vicary Creek	1967-82	18.5	1.1	5	9.5	20-23	0.6	6	2	10.850
Luscar	1970-85	15.0	1.0	6	8.5	24-26	0.37	5-7	1.5	13.680
Smoky River	1970-85	29.5	1.5	6	6.3	17-20	0.55	7-9	1.5	18.090
Smoky River No. 9	1974-89	45.8	-	6	6.3	17-20	0.55	7-9	1.5	21.800
Fording River	1972-87	45.0	-	6	8	21-24	0.45	5-7	1.5	13.850
Stewart	1968-78	1.3	0.2	6	9	16-17	0.6	6-8	-	15.080
Poland										
Composite	1974-84	25.0	-	7	5.5	26-28	0.75	8-9	2	25.000*
South Africa										
Witbank composite	1972-86	27.4	-	7	7	32-35	0.7	2.5	1.25	11.190
U.S.A.										
Itmann	1967-83	65.6	3.9	4.5	5.5	16-19	0.8	7-9	2	20.8[illegible]*
Keystone	1967-81	27.2	2.2	4	5.5	16-18	0.8	8-9	2	21.580*
Beatrice	1967-80	48.4	3.4	4	5.5	16-18	0.8	8-9	2	21.580*
Pittston	1969-79	113.8	10	5	6	28.5	0.65	7-9	2	19.100
B.S. Blend	1969-79	10.5	1.1	5	6	29-30	0.95	7-9	2	18.800
Virginia Pocahontas No. 4	1970-85	27	1.8	4	5.5	17-18	0.67	8-9	2	21.930*
Lancashire	1972-87	10.8	-	5	6.5	21	0.85	9	2	Negotiated Annually
Kellerman	1970-85	9.6	0.4	5	6	30-33	1.0	7-9	2.25	16.830
Swanee	1970-82	10.2	0.9	5	8	28	0.8	7-8	2	19.680
Sunnyside	1971-81	6.5	0.7	7	6.5	40	1.0	4.5-5	2	17.880
India										
W. Bengal	Small shipments un-washed coal			6-25	12-15	24-36	0.3-0.8	1-7	Various	11.70 to 12.50
USSR										
Siberia	1969-75	2.9	N.A	6-8	8.5-9	14-42	0.5-0.6	N.A	N.A	12.80 to 16.70

* cif prices

Source: Imported Coking Coal Manual, Tex, 1971

ANNEX 7

PROCESSES FOR THE PRODUCTION OF TOWN GAS, SNG AND LIQUID FUELS FROM COAL

TOWN GAS

Process	Description
Koppers-Totzek	Gasification of pulverised coal in an atmosphere of oxygen and in the presence of steam. Operates at approximately atmospheric pressure and can use any type of bituminous coal or lignite.
Winkler	Use of steam/air/oxygen blast to produce a "boiling bed" or partially fluidised condition in the fuel charge. Particularly applicable to young coals such as lignite.
Lurgi	Gasification using steam and oxygen at a pressure of 10 to 30 atmospheres. Can use a wide range of non and weakly-coking coals.

SUBSTITUTE NATURAL GAS

Organisation	Process Name	Description
Applied Tech. Corp.	Atgas	Gasification with steam in a molten iron bath followed by methanation. Based on Iron and Steel Industry technology.
U.S. Bureau of Mines	Hydrane	Two-stage fluidised bed reaction, using steam and oxygen, followed by up-grading by methanation.
U.S. Bureau of Mines	Synthane	Fluidised bed gasification with steam and oxygen followed by methanation.
Consolidated Coal Co.	CO_2 Acceptor	Gasification with steam but without oxygen, followed by up-grading by absorption in dolomite of the carbon dioxide produced.

SUBSTITUTE NATURAL GAS
(continued)

Organisation	Process Name	Description
Kellogg	Molten Salt	Gasification of coal with steam in a molten salt bath.
U.S. Office of Coal Research	Bi Gas SNG	Gasification by the injection, through a nozzle, of steam, oxygen and pulverised coal.
Union Carbide	Agglomerated Ash Process	Gasification by steam in a fluidised bed of ash agglomerates.
Inst. of Gas Tech.	Hygas	Hydrogenation of coal/oil slurry followed by methanation.

LIQUID FUELS

Organisation	Process Name	Description
Consolidated Coal Co.	Consol Synthetic Fuel	Dissolution of coal in an organic solvent, followed by hydrogenation of the solution.
F.M.C. Corp.	COED	Multi-stage low temperature carbonisation followed by hydrogenation of the resulting liquids leaving a solid char.
Hydrocarbon Research Inc.	H-Coal	Direct hydrogenation of a coal/oil slurry in the presence of a catalyst and at high temperature.
Oil Shale Corp.	Toscoal	Carbonisation of coal using oil shale technology and leaving a solid residue.
U.S. Bureau of Mines	Synthetic oil	Coal slurried in recycled oil. Hydrogen bubbled in and the three phase mixture heated and passed through a fixed bed catalyst.

FIG. 1

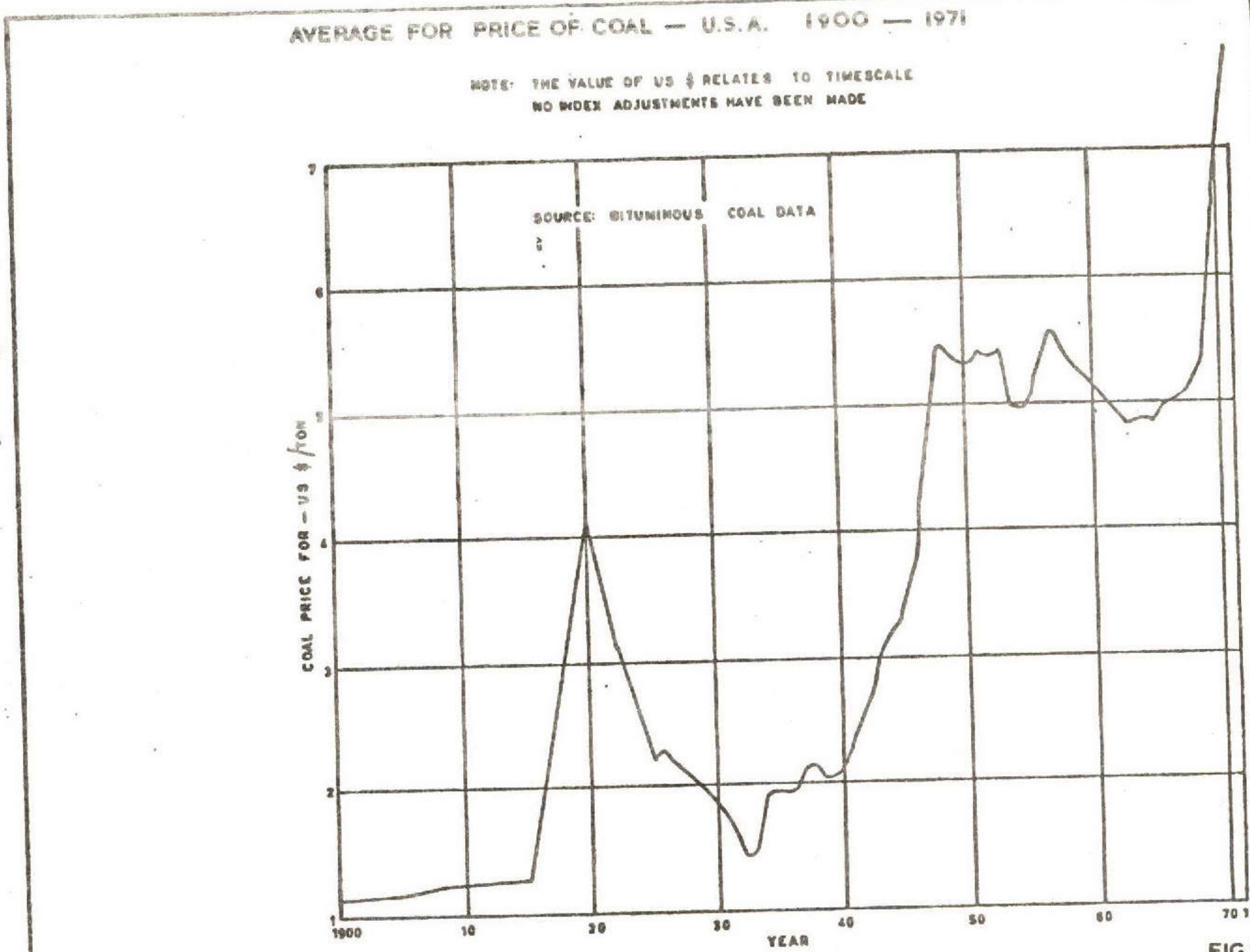

FIG.2

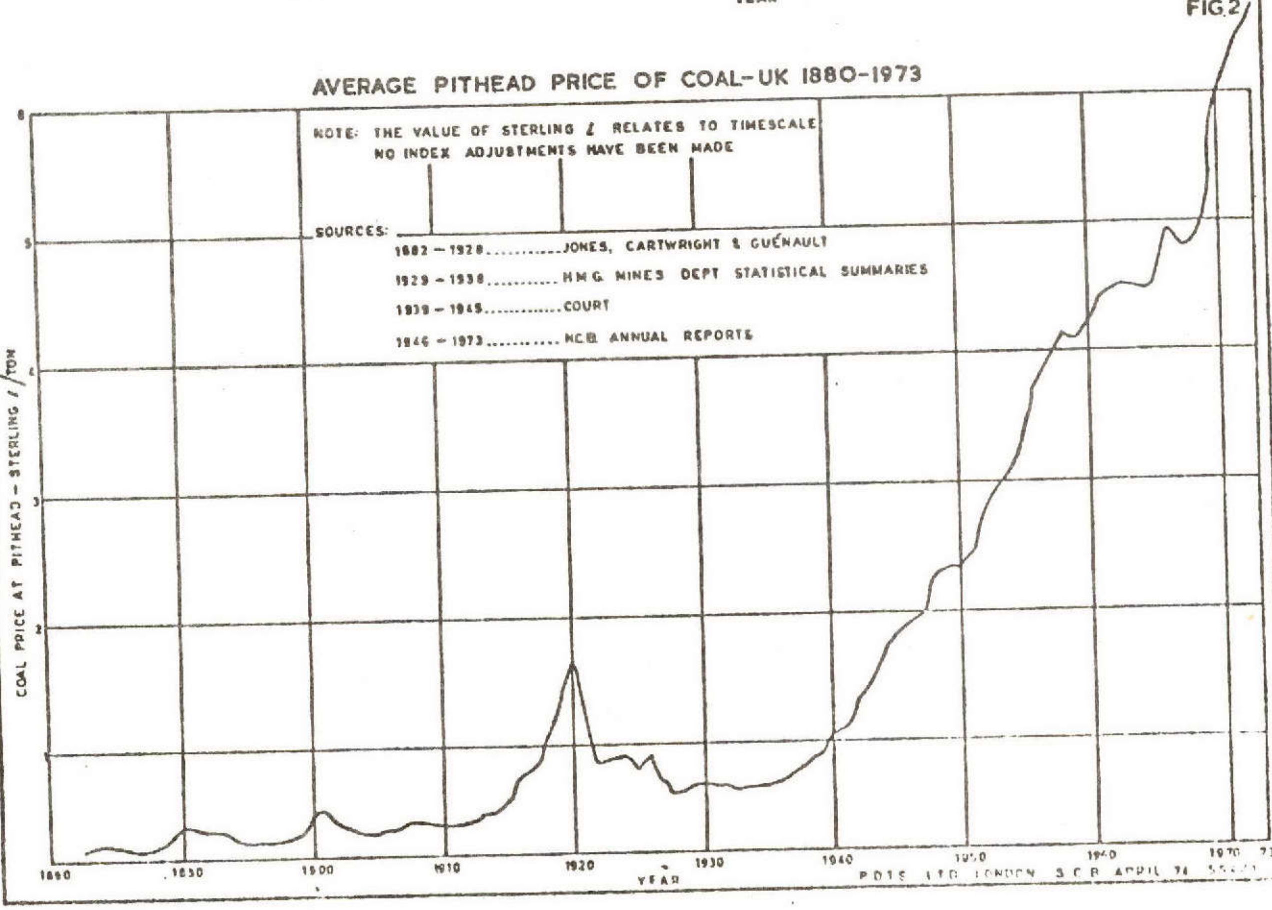

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FIG. 3

COAL PRICES ADJUSTED TO 1972 VALUES

NOTE:

- GERMAN FIGURES — POWER STATION COAL DELIVERED TO DUSSELDORF
- UK FIGURES — AVERAGE PITHEAD PRICES FOR INDUSTRY
- US FIGURES — AVERAGE "FOB MINES"
- CANADIAN FIGURES — AVERAGE VALUE AT MINES FOR INDUSTRY PRIOR TO 1967 SUBVENTIONS ARE INCLUDED
- AUSTRALIAN FIGURES — AVERAGE VALUE AT MINES FOR INDUSTRY

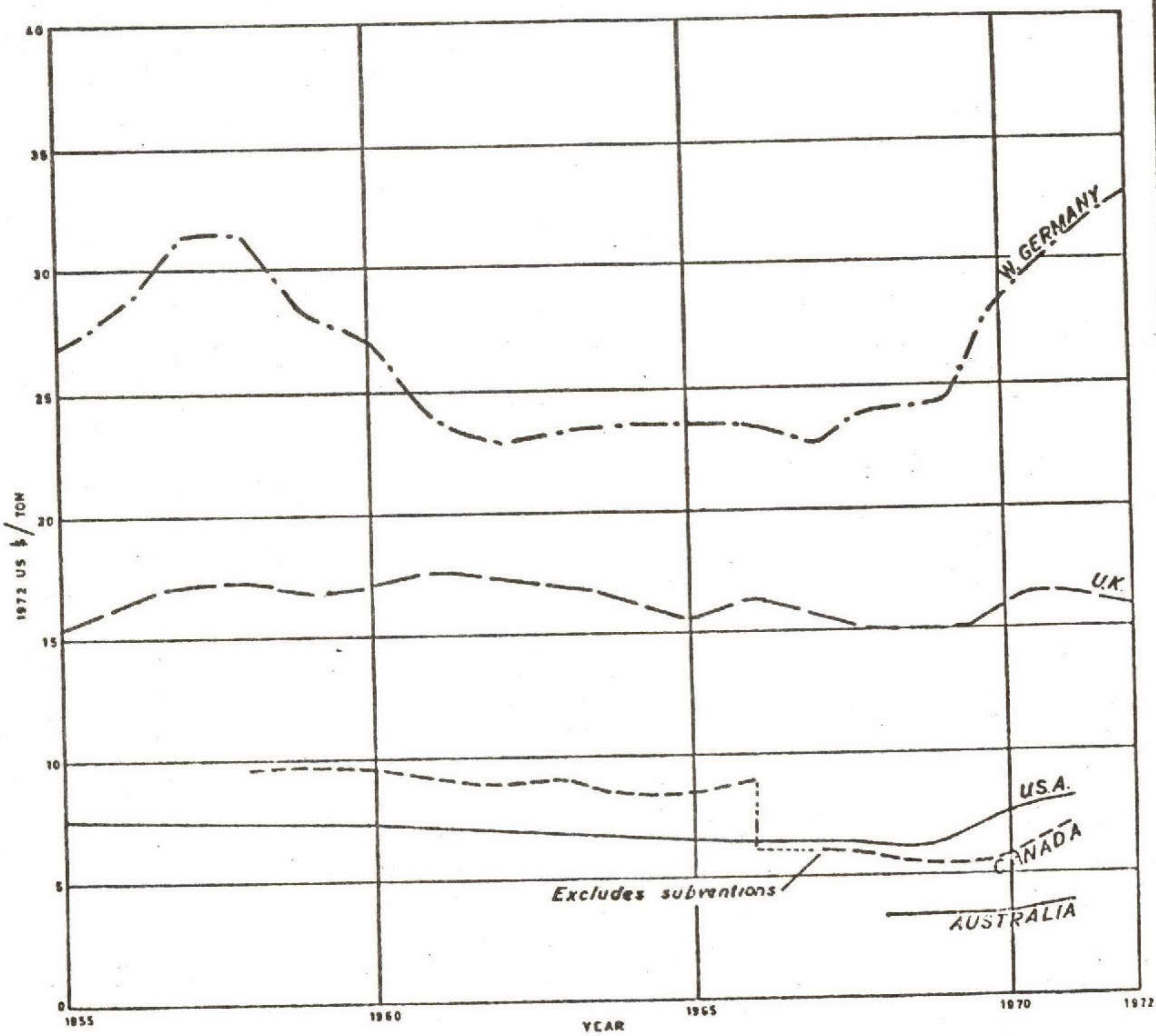

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FIG. 4

AVERAGE PITHEAD PRICE OF COAL — UK 1882 — 1972

NOTE:
THE VALUE OF STERLING £ RELATES TO 1972
WHOLESALE PRICE INDEXES HAVE BEEN APPLIED

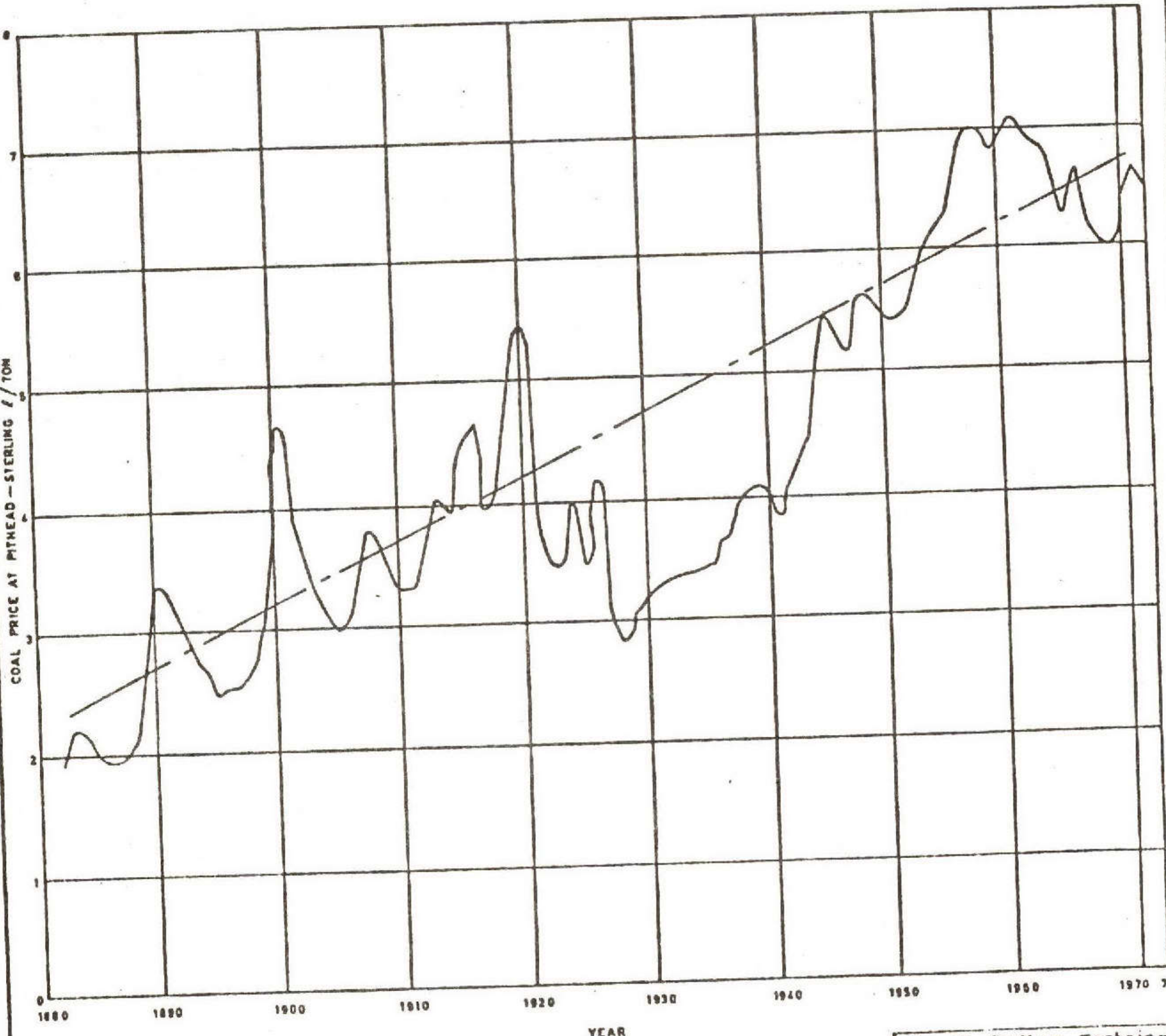
SOURCES:

1882 — 1928 .... JONES, CARTWRIGHT & GUÉNAULT

1929 — 1938 .... H.M.G. MINES STATISTICAL SUMMARIES

1939 — 1945 .... COURT

1946 — 1972 .... N.C.B. ANNUAL REPORTS



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Eng'r SCB	Date. April. 74	Drg. No. 554/3

FIG. 1

AVERAGE FOR PRICE OF COAL — U.S.A. 1900 — 1971

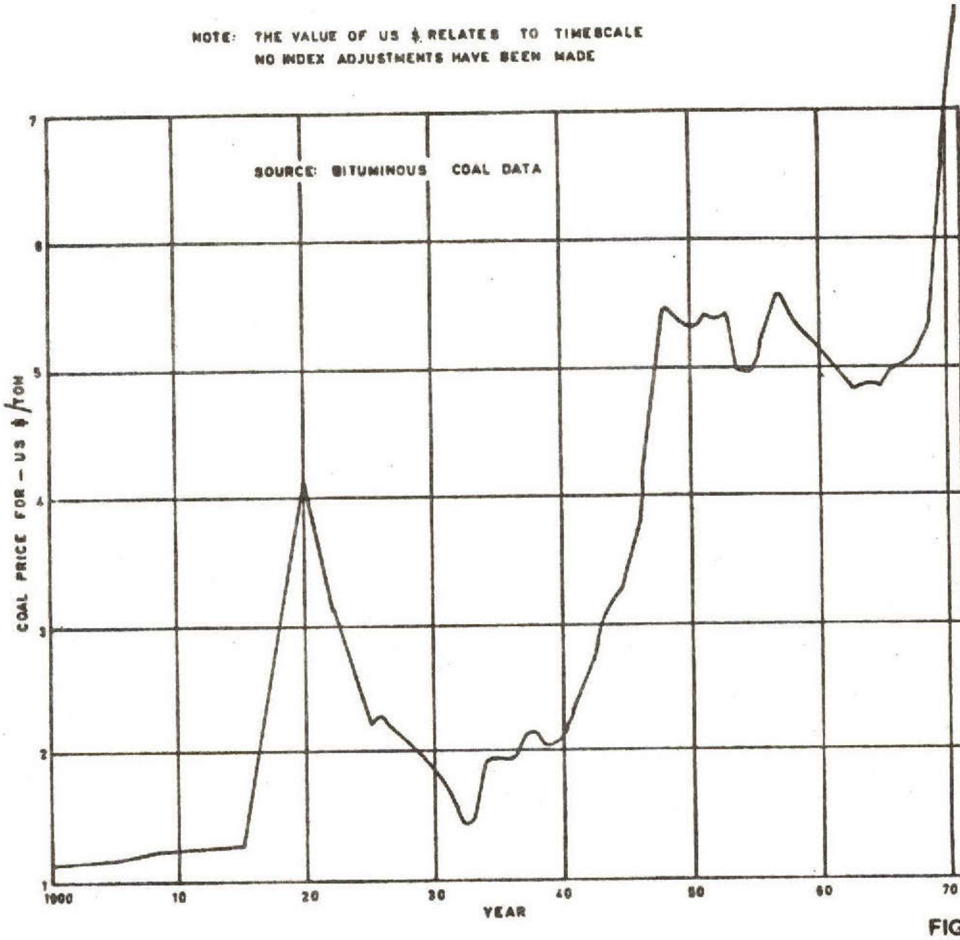

FIG. 2

AVERAGE PITHEAD PRICE OF COAL–UK 1880–1973

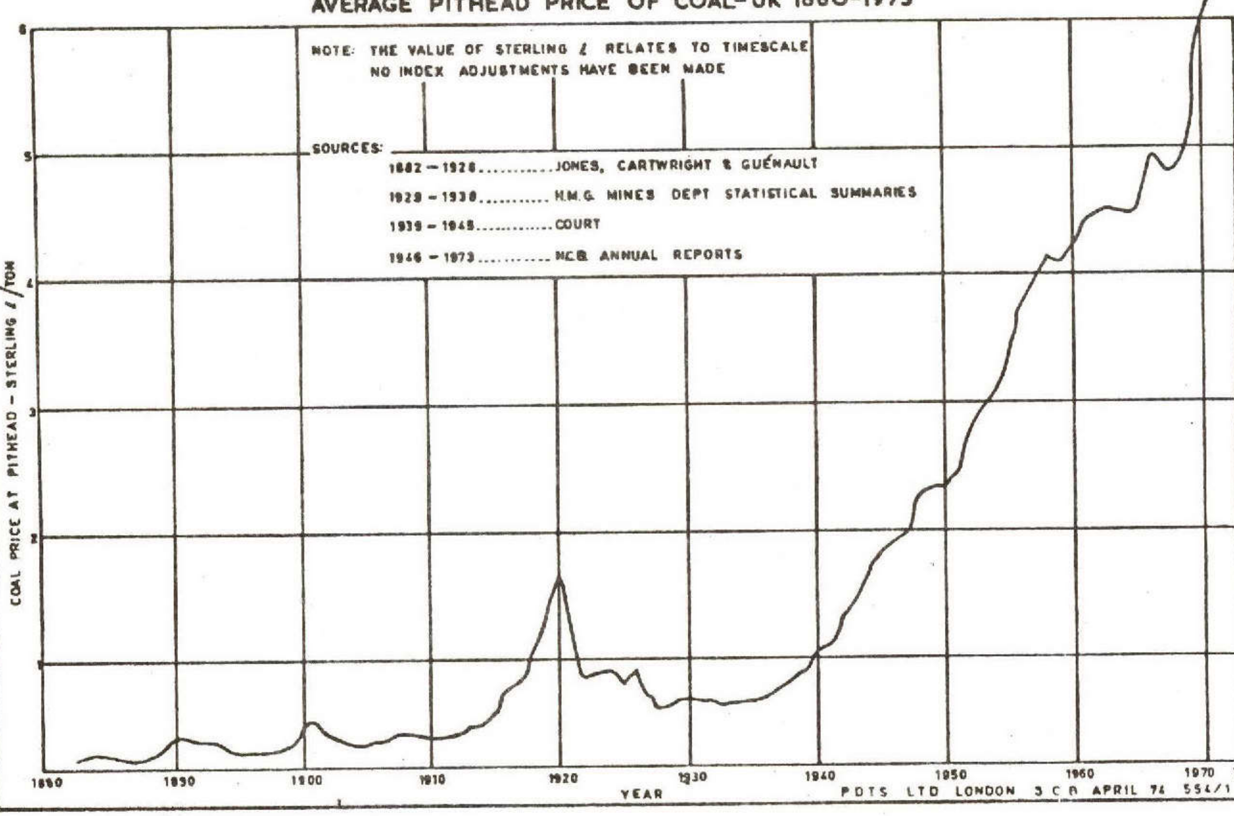

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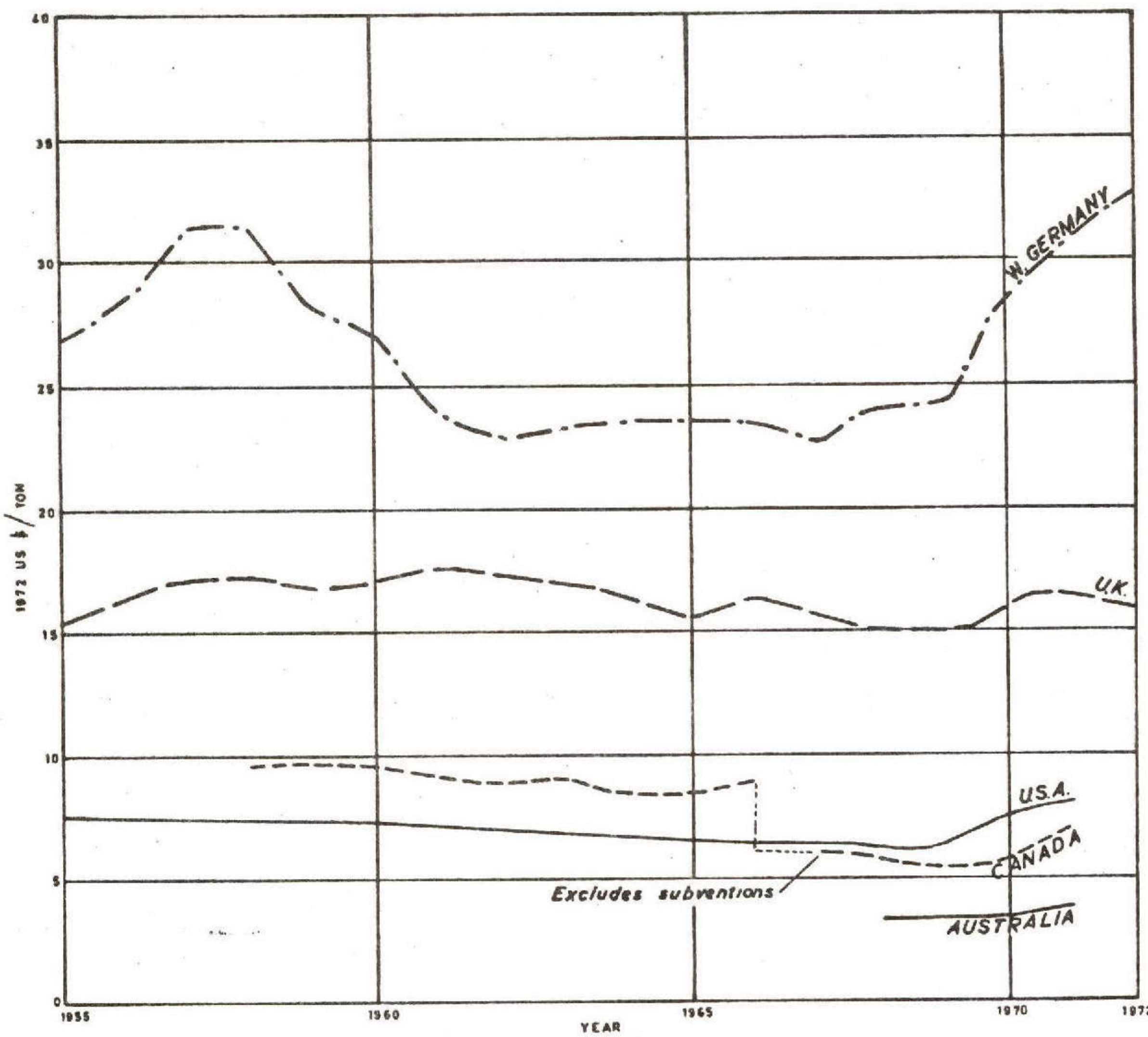
FIG. 3

COAL PRICES ADJUSTED TO 1972 VALUES

NOTE:

GERMAN FIGURES	— POWER STATION COAL DELIVERED TO DUSSELDORF
UK FIGURES	— AVERAGE PITHEAD PRICES FOR INDUSTRY
US FIGURES	— AVERAGE "FOB MINES"
CANADIAN FIGURES	— AVERAGE VALUE AT MINES FOR INDUSTRY PRIOR TO 1967 SUBVENTIONS ARE INCLUDED
AUSTRALIAN FIGURES	— AVERAGE VALUE AT MINES FOR INDUSTRY



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