THE POTENTIAL CONTRIBUTION OF COAL TO WORLD ENERGY FUTURES

MR. LESLIE GRAINGER

NCB (IEA SERVICES) LTD., 14/15 LOWER GROSVENOR PLACE, LONDON SW1.

Introduction - IEA Coal Research

Since IEA Coal Research exists precisely to examine and develop the subject given in the title, this paper will mainly be devoted to describing the activities of that body.

The International Energy Agency was formed in 1974 by O.E.C.D. countries, in response to problems arising from discontinuities in the supply and price of oil at that time. One objective of the IEA was to encourage alternative to oil, especially through Research and Development programmes of a collaborative nature. The potential energy alternatives were divided into discrete technical fields; the U.K. was nominated the lead country for coal. Certain projects were initally proposed in 1975 and were each accepted by a sufficent number of countries to make a viable set of programmes. The principles behind these inital proposals have proved durable. The early progress of the work has already provided substantial new information, both technical and also about the methods by which countries can work together. This experience, assisted by the fact that IEA Coal Research is detached from immediate responsibilities within the coal industry and therefore in a more objective position, is allowing a clearer picture of the future world potential for coal to be developed progressively.

The IEA provide no central funds for the R & D groups and there were initally no administravtive procedures of finacial conventions. The only asset at the beginning was that most of the countries who had joined IEA through their mutual interest in the problems of oil dependance also perceived that coal provided a means of alleviating those problems and were willing to send representatives, generally without madates however, to the early meetings of a Coal Working Group.

From the outset it seemed essential that the Working Group should sponsor one major "hardware" project. However, it also seemed that several questions needed to be answered if the IEA countries were to be influenced further in the direction of coal, both for long-term resource planning and for short and medium term R & D programming. It was proposed that this should be done by the establishment of "Service Projects" or office studies. The service projects and the questions they were designed to answer are:

(a) Resources and Reserves. Is the coal really there? In circumstances making economic recovery plausible? Can output be greatly increased and the product made more widely available?

(b) Mining Technology Clearing House. Is the technology for recovering coal adequate? Is the technology capable of developing in ways which will meet increasing stringencies in human and environmental

(c) Technical Information Service. Is the coal industry fragmented and disunited or is it capable of co-operation in order to maximize the impact of developing technology on an international scale?

(d) Economic Assessemt Service. Will coal be economically competitive? How, when and where.

The hardware project chosen was Pressurised Fluidised Bed Combustion (PFB) at a total programme cost now expected to be in excess of $40m. The annual cost of the Service projects described above is of the order of $2m. An organisation, referred to here as IEA Coal Research, has been set up to carry out this work, to make further proposals and to exploit the achievements for policy guidance.

Resources and Reserves of Coal

The World Energy Conference (WEC) is the best current source of information on energy resources, since the different sources are discussed both separately in relation to each other and because such a wide spectum of countries participate in a constructive manner. Thus, whatever uncertainties there may be in the data, the results and conclusions have a very important political validity.

The WEC Coal Resources Study was carried out by Peters and Schilling of Bergbau-Forschug, Germany; their results, which were not in any way challenged, are summarized in Table 1; Fig. 1 shows the planned coal production. "Technically and Economically Recoverable Reserves" are those which could be produced using current technology at a cost which would be economic at current prices. These reserves, defined on this stringent basis, represent only 6% of the total resource base but would nonetheless last for 250 years at current outputs. Only a small shift in prices, technology or in accuracy of exploration would be needed to transform a substantially further proportion of resources into the economic reserves category. Furthermore, the resource base itself is still expanding, as a result of increasing interest. Fig. 1 is based on output figures assessed mainly from plans stated by various countries. Line 1, which shows the annual output rising from 2.6b. tones to about 7.0 in 2020, could be achieved even if output were restricted to an operationally conservative level based only on present reserves. If the reserves were doubled, say by a small change in the economic base, line 3 reaching nearly 9.0b. could be achieved and sustained for a very long time. Thus, there can be little real doubt about the feasibility of a very large increase in coal production, so far as technical reserves are concerned. It should be noted that the increase, about 3% per year, follows the trend established over many decades. Producing countries expect to have about 10% of their output available for export. At some time, therefore, perhaps within two or three decades, coal will probably re-assume from oil its former leadership, both as a source of energy and as a form of traded energy.

IEA Coal Research, while welcoming these figures and not doubting their implications, felt that more information would be needed in support of this "second coming" of coal, especially in view of the very important decisions on which would be necessary for exploitation. It is noteworthy that the World Energy Conference is itself becoming more interested in improving coal assessment methods and that the United Nations is arranging a meeting early in 1979 to produce a common classification system as a prerequisite to a world assessment.

IEA Coal Research is linked to the data bank of the U.S. Geological Survey. Its immediate objectives are, first to compare different assessment systems and nomenclatures used in various countries, leading to a common sythesis, and, second to provide a preliminary catalogue of all known World coalfields. The first of these tasks is virtually complete and the second, covering more than 3000 deposits, should be completed early in 1979. It is already clear that there is no reason to beleive that the WEC estimates are over-stated in total.

Aggregations compiled from disparate components do not form a suitable basis for national and international policy decisions, whether these are for investments in mining and utilisation within a single country or for multi-national planning which depends on trading, implying harmonious developments in the exporting and importing countries. The assessment of deposits requires study of the following factors, some of which are interlinked of course:

(i) Existance: how much coal in total exists in the gound;

(ii) Coal type; what sort of coal exists and what are its potential uses,

(iii) Extractability: what proportion of the coal in the ground could be brought to the surface;

(iv) Usefulness: what proportion of coal brought to the surface could be used;

(v) Potential Cost: of bringing the coal to the ground;

(vi) Potential Proceeds: of the coal so recovered;

(vii) Accessibility: whether the coal is immediately accessible or whether some obstacle has to be removed first;

A proposed classification form based on these factors is given in Appendix 1. The definitions of accessibility are:

(i) accessed by current working, or those for whose development capital expenditure has been committed;

(ii) a) accessible to current technology within existing legal and environmental restraints and with existing infrastructure;

and,

b) coal which remains accessible in previously worked but abandoned areas;

(iii) dependant for their exploitation on the provision of infrastructure (transport, housing, etc.);

(iv) accessible only after some defined change in circumstances such as

a) removal of environmental prohibitions;

b) removal of other legal restraints (e.g.licenses);

c) the development of a new technology (e.g. underground gasification);

In the diagram the ratio of costs to proceeds, C/P, is used to provide a measure of economic viability and certain boundaries, at ratios of 1, 2, and 4, are suggested. The setting of these boundaries and the rules for the calculating C and P are difficult matters, which affect the categorisation of "reserves". These reserves may be thought of as being column A of the diagram, at accessibilities 1 down to 3 (including costs of infrastructure). It will be apparent that less knowledge is needed for the lower parts of the diagram.

Some conclusions which may be derived from these early attemps to develop assessment and classification system are:

1. In assessing potential coal recovery it is essential to consider the deposit as a whole and to understand the effect of progressive removal of seams.

2. There is little point in attempting to assess total coal in country or

in a particular deposit beyond the point of ensuring adequate supplies for the next 50 years.

3. It is desirable to establish the physical parameters of deposits to enable potentially recoverable coal to be related to current technology; it is also necessary to ensure that technical research and development is appropriate to its future context.

4. Any new modified system has to be based on the fact that, for the most part, operators generate the information they need and are only interested in wider assessments which benefit their activity. These wider assessments should help to steer the operator as well as national and international policy.

5. Coal is a wating asset and continuation of the policy of taking first the best of what is left is only valid if the second best can or is likely to be recovered later, and if coal to be abandoned is adequately identified.

Mining Technology

This is not the place to explain detailed mining developments but it is important to emphasize the urgency now attached to this subject throughout the world. Substantial success has in fact already been achieved in practice but this is often over-looked, possibly due to adverse publicity over industrial relations. Coal mining technology is likely to be largely transformed over the next couple of decades, probably not through any revolutionary discovery but through an evolutionary procedure using information now available or well advanced in development and, most important, through investment. All this should make coal a more reliable energy source with more predictable costs.

This confidence has been enhanced by the studies so far carried out by the IEA Mining Technology Clearing House (MTCH). Mining research and development has expanded very rapidly recently - there are several time as many scientists and engineers engaged now compared with ten years ago. MTCH has catalogued over 2000 R & D projects in the eight co-operating countries alone and from this has developed critiques and overviews which should help in rationalisation and collaboration as well as suggesting lines for future emphasis. MTCH has boundaries with other IEA Coal Research work, for obvious being with Resources and Reserves. An example is that, since coal is a wasting asset, percentage recovery is becoming an increasingly important measure of efficiency. Monitoring recovery performance is a key function especially in relating recovery to the needs of economy and conservaion now under the impact of changing extraction technology.

Mining technology is closely linked to transport and utilisation. In this connection, particular interest has been focussed on hydraulic mining and transport. This subject, and several others identified through the surveys are currently under consideration as possible co-operative "hardware" projects in mining technology.

Technical Information

A key function of the Technical Information Service (TIS) is the production of Coal Abstracts, a service which was previously greatly missed. A perusal of this journal, incidentally, quickly gives a clear impression of the tremendous current interest and activity in coal. All information is of course computerized, with international links. Besides the standard information service, including the preparation of a Coal Thesaurus, TIS provides, for organisations in member countries, an Enquiry Service and a Selective Dissemination of Information Service. In addition, a series of Special

Technical Reviews of key topics is being prepared; these will review all the available literature on the topic and provide constructive summaries and appraisals, suitable for non-experts but useful also to experts because of the comprehensiveness of the sources used. Reviews already issued include:

a) Underground Transport in Coal Mines.

b) Carbon Dioxide and the "Greenhouse Effect".

c) Combustion of Low Grade Coal.

Topics under preparation or consideration include:

a) Surface Transport of Coal.

b) Loading and off-loading of Coal to/from Ships/Rail.

c) Hot Gas Cleanup.

d) Combustion of coal with control of Particulates and NOx.

e) Methane Prediction in Coal Mines.

f) Monitoring of Coal Quality.

g) Conversion of Oil-fired Plants to Coal firing.

H) Materials Problems During High Temperture Coal Conversion.

i) High Temperature Gas Turbine.

The Review on Carbon Dioxide has been received with particular interest and this applies in general to other matters relating to environmental impact. It is believed that these questions are now of sufficient importance to merit more direct and original investigation than appropriate for TIS and proposals are being made for a separate Service to be established; this might benefit from association with other organisations.

Economic Assessment

This must be the central feature of any organisation studying the future contribution of coal. Even environmental factors have economic impact. The Economic Assessment Service (EAS) considers the cost and availability of coal, its transport and its utilisation, in relation of course to alternatives and different timescales, under the following main headings:

a) Economic and Technical Criteria for Coal Utilisation Plant.

b) Technical and Economic Factors Associated with Effluent Disposal.

c) Cost and Availability of Coal.

d) Transport of Coal.

e) Coal Conversion Economics.

f) Costs of Coal Conversion Plant.

g) Fuel Costs and Demand for Coal.

h) Relative Costs of Coal Based Energy.

Although the conversion of coal into gases and liquids, including feedstocks, is of great importance, combustion is likely to remain the most important outlet for sometime. Accordingly, under (h) above, attention has so far been focussed on:

(i) The competitive position of coal in electricity generation .

(ii) The competitive position of coal in direct heating for industry.

(iii) The competitive merits of gas vs. electricity vs. direct coal heating in industry.

Item (i) is particular importance, especially in view of discussion surrounding the future of nuclear power. In economic comparisons between coal and nuclear power. there remain substaintial uncertainties and areas reflecting judgement or policies, In the case of nuclear power, reports of capital cost vary considerably and fuel costs are also uncertain partly due to uranium resources but also because the fuel cycle has not been closed. In the case of coal, flue-gas desulphurisation (FGD), if needed, may amount to 20% of total plant costs. Finally, interst rates and projections of future real costs are dominant but subjective items and results also depend crucially on load factor. The resulting comparisons are therefore quite complicated and the various nuclear and coal cases overlap substantially. In the U.K., however, at present it is considered that if a "medium cost" nuclear case is compared with coal based generation *without* FGD (not required at present or projected) the breakeven price of coal would be £1.2/GJ. If 100% FGD were required, the breakeven price would be £0.81/GJ (current British price £0.95). Another comparison, on British data, makes the assumption that nuclear capital costs will stabilise either at present levels ("medium") or at 25% higher ("high") and clculates the maximum <u>real</u> annual coal cost inflation which could be suffered for coal to remain competitive. The results are:

100%FGD/medium nuclear	Not competitive
100%FGD/high nuclear	2.2%
No FGD/medium nuclear	2.5%
No FGD/high nuclear	5.3%

In the U.K. such annual rates of coal costs increase do not seem credible, in the light of current investment, nor can 100% FGD be regarded as at all likely. Each country will have its own attitude to FGD but the effect that this has had on the breakeven coal cost - a reduction by one-third, say - should be borne in mind when assessing any benefits from sulphur suppression especially to very low levels.

These studies have now also considered the economic impact of the introduction of Fast Breeder Reactors. At this stage it is very difficult to see how the FBR can be justified even in comparison with thermal reactors without making assumptions which are either incredible with regard to the growth of nuclear electricity or which make thermal reactors themselves much less attractive.

Perhaps more directly relevant, at least to IEA Coal Research, a preliminary assessment has been made of the comparison between conventional coal generating costs (with FGD) and fluidised combustors both atmospheric (AFB) and pressurized (PFB). The first results, expected as percentage savings in electricity cost are:

PERCENTAGE SAVINGS IN ELECTRICITY COSTS

Coal Price	High Sulphur		Low Sulphur	
	AFB	PFB	AFB	PFB
$1/GJ	13-15%	7-8%	<3%	3-4%
$2/GJ	12-14%	9%	<3%	4-5%
$3/GJ	11-13%	10%	<3%	4-6%
OVERALL	11-15%	7-10%	<3%	3-6%

The main "hardware" project of IEA Coal Research is an experimental unit based on PFB. This project has been described eleswhere. It is expected to be commissioned in the early Spring of 1979 and has initially a two year programme of work mainly on combustion factors, with particular attention to the quality of off-gases for direct use in turbines. Proposals for adding a gas turbine, which would effectively convert the test equipment into a pilot plant, are being considered. The earlist that this could be completed is about the end of 1981 which probably corresponds to the need to complete the basic combustion programme first.

The preliminary economic assessment quoted above, whilst showing reasonable potential for fluidised combustion power generation where FGD must be practiced on high sulphur coals do not show much saving with low sulphur or any advantage for PFB over AFB. This obviously calls for collaboration between the technical and economic studies. Apart from better engineering to reduce capital costs, from which the more complex system should benefit most, consideration will have to be given to other ways in which the competitiveness of PFB can be increased initally as a guide to further experimentation. In the calculations above, PFB, is taken as having only 3 percentage points advantage in thermal effeciency over AFB. Clearly if this can be increased, so will the economic benefit and this would be compounded by fuel price increase. Thus, great emphasis must be put on thermal efficiency, which is most likely to be increased by higher temperatures. In addition, the system itself will nedd further examination, including continuous reconsideration of the duty of PFB, in conjunction with other processes and within the broader study of energy flows.

Similar studies to those described above on combustion will be required on other coal conversion processess and these are in hand by EAS, as are combinations of processes (Coalplexes). Coalplexes, intermediates may be transferred and more than one product is available. It is likely that hydrogen costs will be a key factor in economic studies in the future, not only for coal but for the whole family of fossil fuels. This has led to suggestions of a sequential use of hydrocarbons and this may result in separation procedures as an initial step in coal processing, in order to recover fractions having a higher hydrogen content or small molecular size; the residues could be gasified and/or combusted. Obviously, the development of more elegant utilisation systems for coal will require re-optimisation of quality requirement for mining and preparation of transport methods.

Conclusions and Predictions

The resources of coal are very large indeed, so large that the rate at which the world decides to exploit them is a matter of choice based on economics and investment policies, rather than resource constraints. It seems highly probable that output will be increased several-fold over the next few decades, without the danger of a sharp peak followed by a rapid decline which may occur in the case of oil and gas. Coal is fairly well distributed and is readily transportable and storable, so that trading should become much more important in the wake of oil. Practically all countries should therefore seriously consider their policies for coal and most would benefit by doing so through international collaboration. Countries possessing ample coal may need capital to make large investments in developing these resources; potential importers need to invest in handling and utilisation equipment. Coal may be transported as such or converted into coal products in the producing countries and the merits the alternatives need careful consideration on a case-by-case basis. Partnerships between producers and users should therefore be formed at an early stage and a wide range of options involving current and future processes considered.

The understanding of how to get and how to use coal is developing progressively. Within individual countries a new approach to mining and distribution is necessary. Hydraulic mining and transport, for example could help to separate mining from its traditional environmental impact and might also provide flexibility in the location of energy conversion and comsumption centres. Utilisation patterns will certainly change sequentially, in timescales which may be consistent both with the peaking and run-down of other hydrocarbons and also sequence from low to high value uses will be based on adding more hydrogen which will increasingly be derived form coal.

The development and economic progress of new coal conversion processes will call for re-optimisation of all the stages in getting, preparing and using coal including schemes where the more valuable portions are removed before the residue is used for the crude outlets. Envisaging the complex nature of the coal industry in the next century is perhaps more difficult than trying to see the modern petroleum industry from its origons at Titusville might have been. Still, it should be attempted now and progressively updated.

For the present however the most important outlet for coal is combustion. For electricity generation coal is likely to continue to compete successfully and will become very important for direct heating. Fluidised Combustion, in various forms, will be the main contributing technological factor.

All countries will be affected by the optimal use of coal will all benefit from the extension of collaborative arrangements. IEA Coal Research has demonstrated some ways in which this collaboration might progress.

Hard Coal (bituminous coal and anthracite)

Continent	Geological resources in 10^6 t. c. e.	percentage	Technically and economically recoverable reserves in 10^6 t. c. e.	percentage
Africa	172 714	2	34 033	7
America	1 308 541	17	126 839	26
Asia	5 494 025	71	219 226	44
Australia	213 890	3	18 164	4
Europe	535 664	7	94 210	19
Total	7 724 834	100	492 472	100

Brown Coal (subbituminous coal and lignite)

Continent	Geological resources in 10^6 t. c. e.	percentage	Technically and economically recoverable reserves in 10^6 t. c. e.	percentage
Africa	190	--	90	--
America	1 408 838	59	71 081	49
Asia	887 127	37	29 626	21
Australia	49 034	2	9 333	7
Europe	55 241	2	33 762	23
Total	2 400 430	100	143 992	100

Total

Hard Coal	7 724 834	76	492 472	77
Brown Coal	2 400 430	24	143 992	23
Gesamt	10 125 264	100	636 364	100

Table 1 : The Distribution of World Coal Resources, grouped by Continents

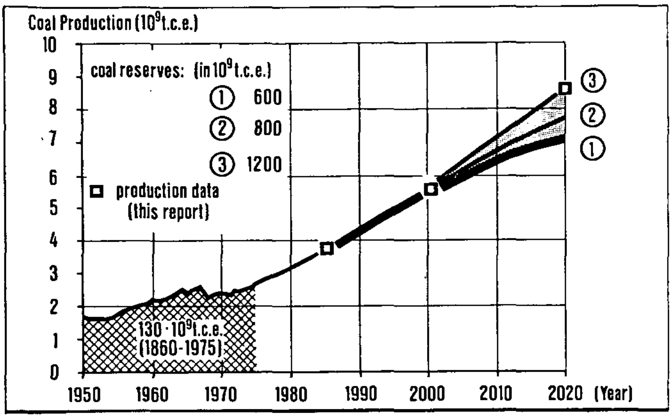

Fig. 1 : Future Trend in World Coal Production, based on Different Amounts of Coal Reserves

Appendix 1

MAIN CLASSIFICATION

Date of assessment.......

Coal type........... Location................

Decreasing accessibility ↓ Decreasing economic viability →

tonnes x 10^9

Access Category		Assurance Bracket	Economic Category: Coal recoverable at:- A $C/P \leqslant 1$	B $C/P \leqslant 2$	C $C/P \leqslant 4$	D Coal in place
1	1. Accessed	most likely maximum minimum				
2	2. Accessible	most likely maximum minimum				
(a)	Total of 1 & 2	most likely maximum minimum				
3	Accessible after provision of infrastructure	most likely maximum minimum				
(b)	Total of 1, 2 and 3	most likely maximum minimum				
4	Accessible subject to other conditions	most likely maximum minimum				
(c)	Total of 1-4	most likely maximum minimum				
5	Inaccessible	most likely maximum minimum				
(d)	Total 1-5	most likely maximum minimum				

Notes: 1. Economic category A is included within B, B within C and so on.
2. Access categories 1 to 5 are separate from one another and do not include one another.
3. The most usual view of 'reserves' - currently economic accessible coal - is represented in Column A, line (a).
4. Coal in place (Column D) may be limited by excluding coal below a a given thickness or depth, varying from country to country. Such limits will be recorded.