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Follow-up Action on First
Consultation Meeting on the
Iron and Steel Industry

WORKING PAPER*

FOR

THE WORKING GROUP MEETING

ON

COKING COAL

Vienna, 6 - 8 April 1978

prepared
by
The Secretariat of UNIDO

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Introduction

1. The Report of the First Consultation Meeting held in Vienna from 7 to 11 February 1977 recommended that:

"In co-operation with the parties concerned, the UNIDO Secretariat should examine the following topics so that it could make specific proposals to the next consultation meeting concerning ways of promoting international co-operation to ensure the availability of the raw materials and fuels needed for the expansion of the iron and steel industry:

. . . .

"(b) A review of known reserves of coking coal and the identification of probable resources;

(c) A review of the plans and progress made in developed and developing countries to increase the production of those raw materials and consideration of whether appropriate measures were being taken to ensure an adequate supply of them;

. . . .

(e) A survey of the alternative techniques including sponge iron that might be used to replace coking coal by other fuels and reductants, including processes for the gasification of coal, and the use of formed coke or charcoal, taking into account the returns from alternative uses of those raw materials." (ID/WG.243/6/Rev.1, para. 23)

2. The UNIDO Secretariat proposed action to carry out these recommendations to the Industrial Development Board and the Bureau of the First Consultation Meeting. The proposals on the following lines were agreed:-

"Due to the high priority attached by the First Consultation Meeting to the issue of coking coal, all recommendations related to this issue will be submitted for examination to a separate working group. The terms of reference of that working group will be to consider:

"(i) Present situation and future prospects of the reserves, production and international market of coking coal, including access to its supplies;

(ii) Present status and availability of alternative technologies that might be used to replace or economize the utilization of coking coal." (ID/B/179, para. 37 (d))

3. This working paper summarizes the results of a survey on coking coal resources and their development carried out by UNIDO consultants, and a review of published information available to the Secretariat. It presents a number of topics for the consideration and opinions of the Working Group with a view to formulating proposals for action to the second Consultation Meeting to be held early in 1979.

Agenda item A: Present situation and future prospects of the reserves, production and international market of coking coal, including access to its supplies

A.1 - Reserves

4. World reserves[1] of coking coal[2] are estimated to be some 121 billion tons, i.e. about 24% of the total hard coal reserves, as shown in detail in Annex 1. At the present coking coal production rate (630 Mt/y in 1975) the reserves would correspond to nearly 200 years' supply.

5. However, the geographical distribution of the reserves is very uneven in the world. Three countries possess 72% of the world coking coal reserves (USA 32.4%, China 20.5%[3], USSR 19.0%). With the addition of seven further countries (Australia, Poland, FRG, India, South Africa, Canada and UK), the top ten countries hold virtually all the reserves of the world, namely 97.8%. Developing countries other than China and India have only a small fraction of the world reserves (some 0.6%).

6. Qualities are important in considering reserves of coking coals. They can be divided into at least two groups, premium and blending grades. Premium grade coking coal refers to those types of hard coals which are essential for the conventional coke oven process and have characteristic features of high cokability[4] and high purity[5]. Blending grade refers to those types of coals

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1/ Reserves refer to known recoverable quantities under the present economic conditions.

2/ Coking coal refers to all types of coals that can be converted in conventional coke ovens into coke for metallurgical use.

3/ The data given in this paper on the People's Republic of China is uncertain, but an attempt has been made to include estimates because of the country's significance in considering the coal and steel problems of the world.

4/ Generally as presented by the high swelling number (not under 7), high dilatometric expansion (not under 100%), and low or medium volatility (not above 31% on dry basis).

5/ Generally sulfur less than 1.25% and ash less than 8%.

which can be used as additives in the coal mixtures to be converted into metallurgical coke in coke ovens.

7. The distribution of reserves of premium grade coking coal is much more limited than that of total coking coal. Countries with substantial reserves (more than 1,000 Mt) are only USA, China, USSR, FRG, Poland, Canada and India.

8. The lack of information on further sub-divisions of coking coal qualities or of international indices which signify coal qualities, makes it difficult to analyse the reserves in qualitative detail and thus to be fully confident about their adequacy.

9. Intensive exploration of coal reserves is underway in various regions and countries. Hard coal reserves estimated by the Xth World Energy Conference, 1977, for example, increased by 3% (15,000 million tonnes) over the figure at the IXth Conference three years earlier. The main countries which showed substantial increases in reserves by new exploration or re-evaluation of the data were Canada, Australia, South Africa, UK, Poland, India, Brazil, Colombia, Peru, Venezuela, Botswana, Mozambique and Swaziland. Estimates of the reserves of coking coal in such countries as Canada, Australia, Brazil, Colombia, Venezuela, Botswana, Mozambique, India, Indonesia and Iran are likely to benefit from such intensive exploration.

Questions:- Does the Working Group subscribe to the reserve data described above?

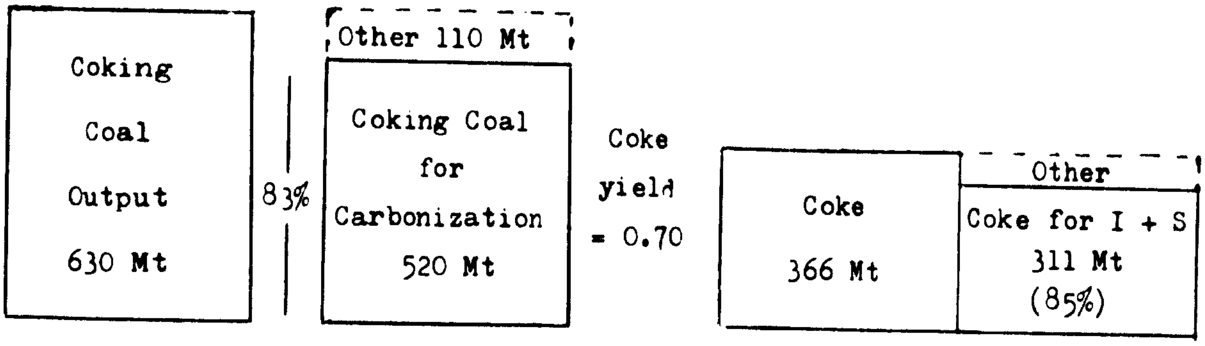
- Is it necessary to establish a common international index signifying coking coal qualities? If so, what will be the role of UNIDO in encouraging such work by other institutions?
- What measures should be taken to intensify exploration for coking coal reserves, particularly in developing countries?
- What has been the experience of developing countries in exploring for reserves, referring to finance, technology and conditions of international co-operation?
- In which areas is regional co-operation in exploring for reserves feasible?

A.2 - Prospects for demand and supply

10. The steel industry is the largest consumer of coking coal. However, it is worth mentioning that a considerable part of coking coal (some 17%, probably of blend coking coal quality) is still burnt for thermal purposes and 15% of

coke produced is used in sectors other than the iron and steel industry, as illustrated in the chart.

Chart
Simplified global picture of the use of coking coal and coke in 1975 (partly data and partly estimated)



11. Considerable structural changes have taken place in the use of coking coal and coke during the last decade. While coking coal output rose only 4.0% in ten years from 606 Mt in 1965 to 630 Mt in 1975, pig iron production increased by 43.6% from 330 Mt in 1965 to 474 Mt in 1975. This was mainly due to a substantial decrease in the coke rate (some 100 kg/t-pig) and to the decreasing use of coking coal outside the steel industry.

12. Future demand for coking coal depends on the steel production level and the coke economy to be achieved. Table I shows estimates of the coking coal requirement for carbonization in the world in the years 1985 and 2000.

Table I
Estimated coking coal requirements for carbonization for all purposes including iron and steel

			1985		2000	
	1965	1975	Alt.1	Alt.2	Alt.1	Alt.2
A. Steel Production (Mt)	461	646	1,050	900	1,750	1,400
B. Coking coal for carbonization (tons per ton of steel)	1.041	0.805	0.700	0.725	0.600	0.650
C. Consumption of coking coal for carbonization (Mt) AxB	480	520	735	653	1,050	910

13. Two variants of future steel production were assumed for Table I. Alt.1 represents figures discussed at the first Consultation Meeting and Alt.2 those selected by a UNIDO consultant for the survey of coking coal problems. Item B is related to steel production but allows for the proportion of coke used outside the steel industry. The table assumes:-

a) that economy in the use of coking coal and coke in the steel industry will be further pursued by various technological developments to be discussed under Agenda Item B. The higher the steel production level the more vigorously the economy measures will be pursued;

b) a decrease in coke use outside the steel industry cannot play an important role in decreasing coke requirements.

14. Estimates of hard coal and coking coal production in the world are shown in Annex 2, together with actual 1975 figures. These are summarized in Table II.

Table II
Estimates of world hard coal and coking coal production

	1965	1975	1985	2000
A. Hard coal (Mt)	2,007	2,423	3,070	4,395
B. Coking coal (Mt)	606	630	750	950
Share of coking coal %	30.2	26.0	24.4	21.6

The above estimates take into account the future prospects for coking coal mine developments in countries such as USA, Canada, USSR, Poland, FRG, UK, Austria and India. They assume that:-

a) the growth of hard coal output in the period up to the year 2,000 will be 2.3 - 2.4 % yearly (between 1965 and 1975 it was 2.0% yearly);

b) the coking coal reserves are about 24% of total hard coal reserves;

c) the geological and mining conditions will continue to worsen; concentration and mechanization of mining operations will decrease the ratio of saleable coking coal to hard coal output.

15. Tables I and II are compared in Table III. The considerable proportion of coking coal used for purposes other than carbonization as noted in paragraph 10 is a significant factor in interpreting this Table.

Table III
Prospects for production of coking coal and consumption of coking coal for carbonization for all purposes

	1965	1975	1985		2000	
			Alt.1	Alt.2	Alt.1	Alt.2
A. Production of coking coal	606	630	750		950	
B. Consumption of coking coal for carbonization	480	520	735	653	1,050	910
The ratio B/A	0.79	0.83	0.98	0.87	1.11	0.96

It is hardly to be expected that the ratio can be increased to more than 0.85 - 0.90 because some coking coal of inferior quality is likely to be permanently used outside coke oven plants due to the local and environmental conditions in the coal producing regions.

16. The above analysis suggests that neither of the steel production estimates for the year 2000 will be met unless:

(i) coking coal production can be more dynamically increased by mine developments beyond those assumed in paragraph 14;

(ii) coking coal and coke use outside the steel industry can be more substantially decreased;

(iii) the coking coal to steel ratio can be more drastically decreased by technological development than assumed in paragraph 13.

With regard to coal mine development the factors which must be considered are: the time required for the new mine development, the huge investment required, the infrastructure to be developed, environmental protection and national energy policies.

Questions:- Is the assumed requirement of coking coal for carbonization to produce one ton of steel for the year 1985 and 2000 realistic? (Table I).

- In what area, to what extent, and how can the use of coking coal and coke outside the steel industry be decreased?
- Are the estimates of world hard coal and coking coal production in 1985 and 2000 too pessimistic? (Table II).
- What measures should be taken to encourage development of coking coal mines in major producing countries
    - by producing nations,
    - by consuming nations,
    - at regional level,
    - at international level?
- What will be the prospects for developing coking coal mines in developing countries? How can regional and international co-operation play an important role in this connection?

A.3 - Arrangements for securing access to supplies of coking coal

17. Because of its indispensability in the steel industry, its geographically uneven dispersion, and the inelasticity of production in responding to changes

in steel production, coking coal particularly of premium grade constitutes a special market. The characteristics of the market are:

(i) heavy dependence of the consuming countries on supplies from USA, Canada, Australia and Poland, particularly the USA because of the quantity and quality of its coal;

(ii) a large volume of inter-continental trade (including W. Europe - E. Europe trade). In 1975 it was some 111 Mt and expected to increase to 182 Mt in 1985 and 250 Mt in 2000 (excluding China);

(iii) heavy dependence (some 90%) of international trade on long term contracts with the balance on a spot basis;

(iv) upward trend of costs and prices. The price of premium grade coal is closely related to that of oil.

18. These features of the coal market may create difficulties of access for the developing countries which currently have and will be establishing a steel industry based on the blast furnace route. Developing countries (except India and China) have to import 50-70% of premium grade coking coal to blend with 30-50% of indigenous blending coal. Some developing countries are able to secure deliveries of coking coal on barter contracts against iron ore, crude oil and natural gas. For those countries which cannot establish barter arrangements there may be a heavy burden for their foreign exchange if long-term supply contracts have to be linked with participation in new mine development.

19. The steel industry development plans of many countries could be hampered by inadequacy of coking coal supplies, unless appropriate and timely action is taken. Most of the new demands will be largely dependent upon supplies from new pits, which must be created with huge investment and years of development work.

<u>Questions</u>:- What is the experience of developing countries in buying coking coal? Is it really a problem to obtain access to a coking coal market? How are some developing countries such as Algeria, Argentina, Brazil, Egypt, Korea, Mexico, Peru, Venezuela, securing deliveries of coking coal?

- Is the long-term contract the only way to secure coking coal? If so, are the current conditions of long-term contracts agreeable for the developing countries?

- Is it useful for developing countries to formulate a model long-term contract? If so, what action should be taken to formulate the model?

- Should UNIDO organize a working group between buying countries with small demands for coking coal and a few selling countries, and help to define the terms and conditions of the contracts?

- What are the prospects and limits of co-operative buying of coking coal by regional or sub-regional groups?

- Are there any effective measures to cope with the disparity between changes in coking coal demand and inelasticity of mining capacities? Are stocking arrangements of coking coal feasible for that purpose?

Agenda item B: Present status and availability of alternative technologies that might be used to replace or economise in the use of coking coal

20. In order to reduce the problems of the limited supply of coking coal, many attempts to reduce coking coal consumption and replace coking coal by other reductants have been made in many countries. Most of the technologies developed for this purpose are illustrated in Annex 3. The following are questions which arise from the description below of the groups of technologies.

Questions:- What is the present status and future prospects of each technology; if not commercialized yet, when would it be commercialized; how significant would it be as a solution of the coking coal problems; what are the important techno-economic parameters which decide the selection and development of the technologies?

- Is the information on these technologies well publicized; if not, what kind of information is particularly lacking; what should be done to encourage such publication; if UNIDO organizes study tours on some of these technologies, would it be useful for developing countries and acceptable to developed institutions?

- Are there any worldwide investigations to collect the views of well informed experts with regard to the present status and future prospects of these technologies; is it worthwhile to carry out such an investigation by sending questionnaires to leading institutions in this field; if so, how and by whom should it be done?

B.1 - Coke economy in blast furnaces

21. Blast furnace injection with oil, natural gas and tar or pitch through tuyeres has become common practice in many countries because their replacement

ratio of coke is as high as 1.0 to 1.5; the equipment needed for injection is simple and not costly; economically the process has been advantageous. It is said that 80% of the world's pig iron output produced in 1975 was with injection of additional fuel. The recent drastic price increase in oil and natural gas, however, affected the economic advantage of this practice, and a coke replacement ratio of over 1.3 to 1.4 now seems to be necessary to secure a benefit.

22. Pulverized coal slurry injection through tuyeres which is claimed as being successfully used in several countries has a limited application in the world scene and can be regarded as still in the development stage. The main reasons for limited use seem to be the expensive and complicated coal injection equipment required and the requirement for low ash coals. The current price difference between oil/natural gas and non-coking coal might encourage the development of this process.

23. Although relatively new blast furnaces in developing countries are equipped with fuel injection systems, many are still operating with only coke and some work at a coke rate of 700 kg or more. In such cases, careful examination should be made of coke rate reduction technologies which include careful preparation of charges, sinter/pellet charge, proper distribution of charges in the furnace, blast control and high top pressure operation.

24. It is reported that charging pre-reduced ore is effective in reducing the coke rate considerably (30 kg coke per 10% metallic Fe addition). Where pre-reduced materials are economically available, their addition might contribute to a reduction in coking coal requirements.

25. Research on reducing gas injection at stack level has been carried out in several institutions. Some results are encouraging, but many studies have to be done not only from the technical but also from the economic point of view before this process can be applied industrially.

26. Charcoal based blast furnace ironmaking is a well established process and is currently used in several developing countries such as Argentina, Brazil, Malaysia and Thailand. World production of charcoal pig iron amounts to over 4 million tons a year and a large part of the pig iron produced is being processed into steel. In developing countries where forest resources are abundant and a well organized re-afforestation programme can be secured, this process can be considered as one of the most practical ways to develop an iron and steel industry.

27. Where only low grade coking coal or soft coke is locally available, small and low shaft BFs could be an alternative route to produce pig iron. They have

the merit of low capital investment costs and are particularly suited to small markets. Information on the recent status of such furnaces is scarce. Techno-economic reviews of these furnaces might help some of the developing countries to consider the possibility of installing them.

B.2 - Coking coal economy in conventional cokemaking. Measures to:

(i) reduce consumption of premium grade coking coal;

(ii) enlarge coal grades which can be used in coke ovens;

(iii) improve coke qualities which lead to lower coke rates in blast furnaces.

28. The steel industry has devoted much effort to reduce the consumption of premium grade coking coals by substituting them by more abundant low grade coals. Technologies that have been and are being developed are summarized in Annex 4.

29. Careful control of charges into coke ovens, including blending of charges, grain size adjustment of coal fines, oil spray, etc., is now standard practice in most of the modern coke ovens. The aim of the control is to improve the coke properties produced and may be regarded as a basis for the advanced technologies described below.

30. Pre-heating of coal fines is a very effective way to improve productivity and also improves coke properties. If coke properties are allowed to be the same, non-coking coal can be charged up to some 25%. Some commercial installations are now operating but the process seems to have encountered difficulties in the transport and charging of pre-heated coal fines, particularly in terms of environmental protection. In order to overcome the difficulties sophisticatedly designed equipment is required and such equipment is difficult or impossible to install in existing coke ovens.

31. Dry quenching of red hot coke developed in the USSR improves the quality of coke produced and reduces generation of coke breeze, and the process might thus reduce consumption of good coking coal to some extent. The major impact of this technology lies in energy recovery and it might be widely applied in the near future where energy prices justify such installations. Other advantages of the system are that it can be installed in existing coke ovens, and that it contributes to decreasing the environmental problems of coke ovens. A higher capacity quenching system seems to be necessary for the further spread of this process.

32. A briquette blending coking process, where a mixture of coal fines and coal briquettes is coked in conventional chambers, has been commercially established in Japan. Currently some 20 - 30% of coke production in Japan

utilizes this process, although the saving of coking coal is limited to 30% or so and binder tar and pitch is required for coal briquetting. The process has the advantage that it can be applied to most of existing ovens with only the addition of briquetting equipment, and it minimizes the requirement of premium grade coals.

B.3 - Economy of the direct reduction and other processes

33. Of the many direct reduction processes conceived, only some have reached the commercial stage. There are several processes operating on a small commercial scale or semi-commercial basis but requiring further techno-economic appraisal. Several plants of industrial scale have been shut down because of technical and operational troubles or economic losses. The current DR iron production for use in electric furnaces amounts to some 7 Mt a year of which developing countries account for more than a half.

34. Where natural gas is available at relatively low prices and the steel demand in the country is not large enough to justify installation of multi-million ton BF-LD based integrated works, the selection of a gas reductant based DR process will be a natural conclusion. Under certain circumstances setting up a 2.5 to 4 Mt/y complex based on this process seems to be justified as seen from the examples of SIDOR/Matanzas (4 Mt/y) NISIC/Ahwaz (2.5 Mt/y), USSR/Kursk (2.5 Mt/y), Krakatau/Anyorlor (2.3 Mt/y). However, most of these complexes are still under construction or in the planning stage and it may take several years before the techno-economic appraisal of their operation can be made.

35. Alternative gas reductants have a decisive effect on both capital investment costs and production costs. Therefore there have been significant efforts over recent years to modify the gas based DR process to enable it to accept a wide range of alternative fuels. Most of the processes are now claimed to be technically feasible for a variety of fuels ranging from coke oven gas, naphta and other liquid hydrocarbons through to heavy oil and also coal as SNG. However, only a natural gas and a coke oven gas seem to be economically applicable at the present stage of development.

36. The solid reductant direct reduction process has a long history of development. In spite of the apparent advantage that the process can be operated using non-coking coal and various types of ores, the commercial operation is limited. Operational difficulties experienced in many rotary kiln type furnaces at the development stage of the process may have hindered the spread of the process. Capital costs of SL/RN kiln type DR plant seem to be of

the order of US$100 - 140 per ton of sponge for the plant with 0.65 to 0.35 Mt annual capacity. The economic viability of the process, once the rated capacity is achieved, is essentially dependent on the cost of ore feed and the reductant coal.

37. The recent development of the kiln process with combined gasification and reduction (Allis Chalmers) is interesting because of the wide range of selection of fuels (gas, oil, coal and their combinations) and the relatively low investment costs required (of the order of US$ 75 - 100 per ton of sponge for a plant with 0.6 - 0.05 Mt annual capacity).

38. Ironmaking by electric smelting furnace can provide opportunities to produce pig iron in developing countries where relatively abundant hydro electric power and solid reductants such as coal, coke breeze or charcoal are available. Although the history of this process is old, there are only limited applications in the world (some 50 furnaces with total capacity of some 3 Mt/y). High electric power consumption in the absence of pre-reduction of ore, and explosions which happened during operations at some electric smelting furnaces have been reasons hindering the spreading of the process. With pre-reduction of ore to reduce electric power consumption, the additional stage seems to be economically disadvantageous compared to solid-reductant based DR processes.

39. Melting reduction processes such as jet smelting and Inred, which aim to produce molten iron directly from iron ore by injecting coal powder into the bath, seem to have great possibilities producing iron on a relatively small scale. The flexibility of the choice of raw materials and the energy saving are also attractive. The process, however, is still in the stage of laboratory scale tests and the concept of the process has yet to be examined through the pilot scale.

<u>B.4 - Formed coke and coal gasification processes</u>

40. Formed coke processes are considered by many experts as a significant technology which might solve the problems of scarce and unevenly distributed coking coals. Many countries have been developing their own process, and currently some ten pilot plants with a capacity of over 100 t/d are operating in the world. Several plans to install larger plants have been reported. While some processes have been operating more than 10 years, new large scale installations with different concepts have just come into operation or are under planning. A number of large scale BF trials using formed coke have been carried out without significant operational troubles. None of the processes, however, have been industrially established yet nor have definite construction plans for commercial plants been announced.

41. Before the commercialization of the process, the following techno-economic problems have to be solved in pilot plants and in testing in various blast furnaces;

i) Development of large scale hot forming machine with long life
ii) Development of large scale carbonization furnace
iii) Utilization of by-products
iv) Availability and/or development of binding additives
v) Development of BF operation technologies best suited to the formed coke
vi) Improvement of formed coke characteristics (reactivity, shape, etc.)

42. Because of the time required to solve the above mentioned problems it seems likely to take a further 5 - 10 years before commercial scale plants of formed coke become operational in the major developed countries. The process might eventually have many advantages such as high substitution ratio of coking coal by non coking coal, continuous and automatic operation, closed "non pollution" operation and short process time. Even if some of the processes are industrialized, it may take a long time to substitute significantly for the conventional coking process. The process seems to be very sensitive to the coal grades used, coke ovens have a long life (20 - 30 years), and existing energy systems of steelworks are largely based on coke oven gas which might not be available through the formed coke process.

43. Synthetic coking coal can be produced from coal-derived or heavy oil-derived caking substances. Solvent refined coal (SRC) is an example of this type. Asphalt has the possibility of being a good source of caking substance (apart from sulphur problems). These derived caking substances can be equivalent to good coking coal itself or can be used as a blend with non-coking coal. They can also be used as a good binder for formed coke and briquette blend coking processes. The present status of research is mostly on a laboratory scale and the commercialization of synthetic coals may take many years.

44. The synthetic natural gas (SNG) produced by coal gasification technologies would considerably change the energy consumption pattern of the steel industry if and when it is successfully commercialized. It can be used as the blast furnace injection fuel (both at tuyere and stack level) and as reductant for gas-based DR processes. Large scale R + D work is being conducted in many countries to obtain high calorific gas, and many plans to establish commercial scale plants have been announced.

45. Reliable capital and operating costs for SNG production on a commercial scale are, at present, not available. Costs of SNG are estimated to be several

times higher than the current natural gas prices. These considerations and the fact that sponge iron costs are extremely sensitive to the gas cost lead to the general conclusion that at present coal gasification processes do not offer a commercially viable method of generating a reductant gas for DR processes.

Annex 1. HARD COAL AND COKING COAL RESERVES (million tons)

Country/Region	Hard coal	Coking coal	of which premium grade x/	of which blend coking x/	Ratio 2/1	(%) 3/2
	1	2	3	4		
U.S.A.	117,690	39,287	27,500	11,787	33	70
Canada	11,443	2,530	1,770	760	22	70
I. North America	129,133	41,817	29,270	12,547	43	70
Germany (Fed. Rep. of)	30,000	5,200 1/	5,200	-	17	100
United Kingdom	3,803	1,637	490	1,147	43	30
France	443	350	175	175	80	50
Belgium/Luxembourg	253	200	100	100	80	50
Norway	100	100	-	100	100	-
Spain	552	226	65	161	50	30
II. Western Europe	35,151	7,713	6,030	1,085	22	78
Japan	790	390	195	195	50	50
Australia	13,770	8,537	-	8,537	62	-
South Africa (Rep. of)	24,981	3,451	-	3,451	14	-
III. Industrial Eastern Hemisphere	39,541	12,378	195	12,183	31	2
Botswana	500 x/	?				
India	9,437	4,497	1,500	2,997	47	33
Iran	300 x/	100	-	100	33	-
Korea (Dem. Rep.)	544	163	-	163	30	-
Turkey	134	40	-	40	30	-
Mexico	682	204	-	204	30	-
Columbia	500 x/	200	-	200	40	-
Others	500 x/	?				
IV. Developing Countries	12,597	5,204	1,500	3,704	41	28
V. CMEA Region	186,418	29,185	16,650	10,535	16	57
TOTAL (I-V)	401,850	96,297	55,645	40,552	23	58
China and other DPEC Countries	99,150	(24,787)	-	-	(25)	-
WORLD TOTAL	(501,000)	(121,084)	-	-	(24)	-

Source: IXth World Energy Conference.

x/ Rapporteur's estimate, not existing in original source.

1/ OECD estimate 1972; Survey of Energy Resources figure - 18,000.

Figures in ( ) are inserted by the UNIDO Secretariat.

Annex 2

Estimates of hard coal and coking coal production in the world in 1975 and 1985-2000 /million tons/

Regions/countries	Hard coal output total			Coking coal output					
	1975 x/	1985 xx/	2000 xx/	1975 x/		1985 xx/		2000 xx/	
	mill. tons	mill. tons	mill. tons	value-mill. t	%	value-mill. t	%	value-mill. t	%
1. Europe /incl. USSR/	1.015,0	1,100,0	1.220,0	288,0	28,3	308,0	28,0	340,0	28,9
2. Asia - in this:	661,0	870,0	1.350,0	65,0	9,8	110,0	12,6	170,0	12,61
- People's Rep. of China	470,0	620,0	1.000,0	35,0	7,4	60,0	9,7	100,0	10,0
- India	96,0	150,0	230,0	12,0	12,5	20,0	13,3	35,0	15,2
3. Africa - of which:	75,0	120,0	200,0	10,0	13,3	20,0	16,7	30,0	15,0
- Rep. South Africa	69,0	110,0	160,0	10,0	14,5	20,0	18,9	30,0	18,0
4. North America of which:	590,0	850,0	1.415,0	240,0	40,6	272,0	33,2	350	24,7
- USA	568,0	815,0	1.300,0	227,0	40,0	256,0	31,4	310,0	23,8
- Canada	22,0	35,0	115,0	13,0	59,0	16,0	45,7	40,0	34,8
5. South and Middle America	13,0	20,0	30,0	4,0	31,0	7,0	35,0	10,0	33,3
6. Australia and New Zealand	68,0	110,0	180,0	23,0	33,6	33,0	30,0	50,0	27,8
World total	2.423,0	3.070,0	4.395,0	630	26,0	750,0	24,4	950,0	21,6
7. Share of coking coal i total output, %	26,0	24,4	21,6						
8. Absolute value of coking coal output	630,0	750,0	950,0						

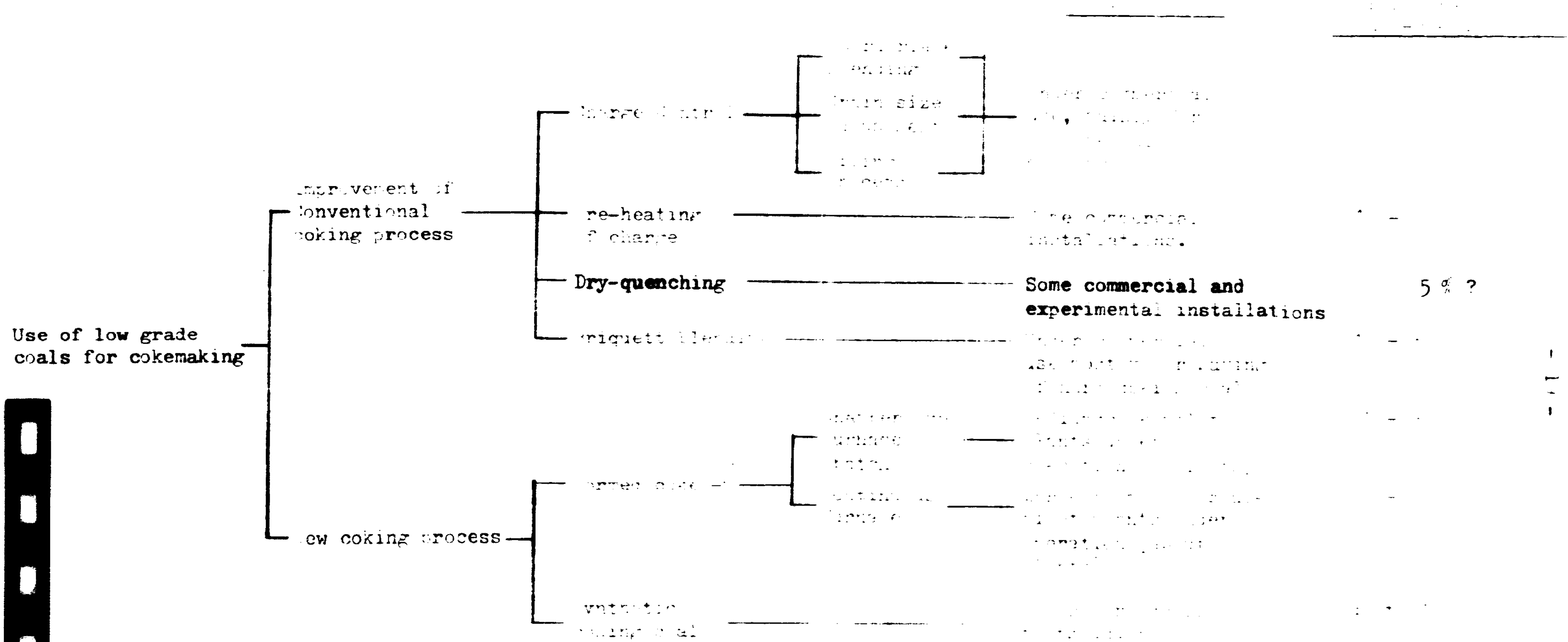
Source: x/-Statistik der Kohlenwirtschaft E.V. Essen und Köln, in September 1977
-World coal Nov. 1976

xx/ - Rapporteurs' estimates

Annex 3. **Representative technologies in the use of alternative fuels in Ironmaking**

		Technologies	Present Status
Use of alternative fuels in Ironmaking	BF route	- Injection of alternative fuels into BF (oil, natural gas, coal, etc.)	Oil injection well established practice. Coal injection and gas injection at st[illegible] level yet to be developed.
		- Use of low grade coal in coke making	Under active development work. Partial replacement of coking coal industrially established.
		- Use of charcoal	Well established practice for small scale furnaces.
		- **Small and low shaft furnace**	Once studied actively. **Viable under limited conditions.**
	DR route	- Use of gases (natural gas, petroleum decomposed gas, coke oven gas, etc.)	**A few processes industrially** established. Up to **0.6** Mt/y unit developed. Further spread in gas rich countries envisaged.
		- Use of solid reductant (coal, coke breeze, etc)	Several, units operating at rather small scale (up to 0.3 Mt/y) Care should be taken to stabilize operation.
	Other routes	- Electric Smelting Furnace	Limited commercial use because of economy of the process
		- **Melting Reduction**	Small scale laboratory scale tests stage. Yet, to be developed first at pilot scale plant.
Related technologies in use of fuels in the Iron **and** Steel Industry		- Coal gasification and **liquefaction (reducing gas** injection to BF, use of by-product **caking** substance for coke production, etc.)	Still not commercially available. If developed, wide use in the steel industry is expected.
		- Nuclear energy (as energy to produce reformed gas from hydrocarbons, hydrogen by electrolysis of water etc.)	Use of this technology in the steel industry may take long time. A few countries conducting basic studies as a kind of national projects.

Annex 4. Present status of the technologies in the use of low grade coals for coke making



1/ Only indicative figures, since substitution **ratios change** largely depending on coke properties required, properties of coking coal to be used, properties of non-coking coal, etc.

2/ For details refer to **chart 4**

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