J. S. Afr. Inst. Min. Metall., vol. 87, no. 11.
Nov. 1987. pp. 371-395.

Presidential Address: Planning the utilization of South Africa's coal reserves*

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SYNOPSIS

Planning the use of South Africa's energy resources, especially coal, is of the utmost importance. The State and the mining industry require reliable official estimates of the economically mineable coal reserves for planning purposes. An overview of all the previous reserve estimates is given, with specific attention to the two most recent estimates—those of Petrick and De Jager. The differences between these two estimates are highlighted.

The following important aspects are discussed:

- the need to update the information regarding South Africa's mineable coal reserves,
- the necessity of understanding and agreement between the coal-mining industry and the State department responsible for updating the coal-reserve data, and
- the importance of the specific assumptions used in the updating of the data.

A downward adjustment of mineable reserve figures is proposed, and the factors that influence the meaningful exploitation of the coal reserves are discussed. A recommendation is made as to how the Waterberg coal reserve should be exploited, and it is concluded that the Soutpansberg Coalfield cannot be exploited economically in the foreseeable future.

An evaluation of the status of the coal-export trade is made and compared with the assumptions and targets set at the start of the coal-exportation scheme. The comparison shows the extent to which the exploitation of the coal reserves is being negatively influenced by the current market situation. Recommendations are made regarding planning for the coal-export market, and the aspects that have to be taken into account to keep South Africa in the export market are identified.

Reference is made to the fact that the present unrestrained wage and salary adjustments, which show a total disregard of South Africa's poor productivity record, require serious thought and speedy rectification if the country is to survive in the export market. A salary and wage strategy must be developed to suit the specific needs of the Republic of South Africa.

SAMEVATTING

Beplanning ten opsigte van die benutting van die energiebronne (veral steenkool) van die Republiek van Suid-Afrika is van die grootste belang. Vir beplanning het die Suid-Afrikaanse owerheid sowel as die Suid-Afrikaanse mynboubedryf dus op 'n deurlopende basis betroubare amptelike ramings nodig van die ekonomies mynbare steenkoolreserwes. 'n Oorsig van alle reserwebepalings wat reeds gedoen is word gegee met besondere aandag aan die jongste twee bepalings, nl. dié van Petrick en De Jager, en die verskille tussen die twee bepalings word benadruk.

Die volgende belangrike aspekte word aangeraak:

- die behoefte aan 'n bywerking van die inligting ten opsigte van die winbare steenkoolreserwes van Suid-Afrika,
- die noodsaaklikheid van begrip en ooreenstemming tussen die bedryf en die Staatsdepartement wat vir die opdatering van sodanige reserwe-inligting verantwoordelik is, en
- die belangrikheid van die spesifieke aannames waarop so 'n bywerking gebaseer is.

'n Afwaartse aanpassing van winbare reserwesyfers word voorgestel en faktore wat 'n belangrike invloed het op die sinvolle eksploitering van Suid-Afrikaanse reserwes word bespreek. 'n Aanbeveling word gemaak ten opsigte van die ontginning van die Waterbergsteenkoolveld en die gevolgtrekking word gemaak dat die Soutpansberg-steenkoolveld nie in die voorsienbare toekoms ekonomies ontgin kan word nie.

'n Evaluasie word gemaak van die stand van die steenkooluitvoerbedryf en dit word vergelyk met die aannames en verwagtinge wat by die daarstelling van die uitvoerskema gegeld het. Die vergelyking dui aan tot watter mate die benutting van steenkoolbronne tans deur die heersende marksituasie benadeel word. Aanbevelings word gemaak ten opsigte van beplanning vir die uitvoermark en aspekte word geïdentifiseer wat in aanmerking geneem moet word indien Suid-Afrika in die uitvoermark wil bly.

Die stelling word gemaak dat onbeheersde loon- en salarisaanpassings sonder inagname van Suid-Afrika se swak produktiwiteitsrekord, dringende besinning verg en dat regstelling nodig is indien Suid-Afrika in die uitvoermark wil bly. Daar moet verder 'n salaris- en loonstrategie ontwikkel word wat spesifiek vir Suid-Afrikaanse behoeftes voorsiening maak.

* The Address as published here is more comprehensive than the presentation at the Annual General Meeting of The South African Institute of Mining and Metallurgy. More data have been included here to afford the reader more background and additional statistics.

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ISSN 0038-223X/$3.00 + 00.

Introduction

Coal is one of the most important resources of energy on earth and makes a major contribution to the quality of human life. For this reason, the availability of coal, expressed as coal reserves, is of extreme importance to man. Since 1913 about ten official estimates of coal reserves have been made in South Africa.

When I was elected Vice President of this Institute in 1985, I decided to dedicate my inaugural address to a review of previous estimates of reserves and to an audit of the coal-reserve figures currently accepted and being used for planning by the authorities. Taking into account all the estimates of reserves made since 1913 and all the factors that do or could influence the extent of South African coal reserves, I re-arranged the coal-reserve figures for the Republic of South Africa as determined by Petrick in 1975 and by De Jager in 1982 for comparative purposes.

This investigation gave rise to a considerable number of questions that I would like to put to members of this Institute, the parties concerned, and the general public. Like my predecessor, Dr H. Wagner, I believe that a presidential address should identify problems that can be solved by discussion and subsequent adjustment or correction and by further studies.

Review of Previous Coal Reserves

The results of all the previous official South African surveys of coal reserves were consulted, and an attempt was made to find a common basis for comparison, with due consideration of the specific assumptions applicable to each survey. Understandably, the results of surveys undertaken decades ago cannot be applicable to present-day circumstances. The objective of this investigation was therefore to establish whether the approach of previous studies, especially that of the two most recent, can be used as a basis for reliable future estimates of reserves.

The results of nine coal-reserve estimates, including the two latest (Table I), are so divergent that further studies are essential in order to make meaningful comparisons possible.

TABLE I
ESTIMATES OF COAL RESERVES IN THE REPUBLIC OF SOUTH AFRICA

Year	Investigating body	Estimate Mt
1913	Dept of Mines[1]	56 245 (*in situ*?)
1928	W.J. Wybergh[2-5]	205 723 (*in situ*)
1947	Coal Commission[6]	11 087 (extractable)
1952	F.A. Venter[1]	67 923 (*in situ*)
1959	Geological Survey[7]	72 467 (*in situ*)
1960	Geological Survey (Bishopp)[8]	10 000 (extractable)
1969	Coal Advisory Board[9]	24 043 (*in situ*)
1975	Petrick[10]	53 945 (extractable)
1982	De Jager[11]	58 404 (recoverable)

The wide range of reserve figures cannot be explained without an evaluation of the specific approach used by every investigating group and without a consideration of the assumptions on which the results were based.

Department of Mines: 1913

The first official estimate of South Africa's coal reserves was made in 1913. As a contribution to the Twelfth International Geological Congress held in Canada in 1913, the Department of Mines submitted a figure of 62 000 million short tons (56 245 Mt) for the coal reserves of South Africa (Venter[1], p. 1vi). South Africa's annual output of coal at the time was only about 7 Mt—an insignificant tonnage compared with the reserves of the country.

W.J. Wybergh: 1922–1928

After World War I, extensive drilling programmes were initiated by various mining companies and, as a consequence of the relatively large volume of information that became available, the Department of Mines decided to determine the country's coal reserves more accurately. The work was entrusted to W.J. Wybergh, former Crown Commissioner for Mines for the Transvaal (Coal Commission[6], p. 27). The results of Wybergh's work were published as *Memoir* 19 of the Geological Survey in three volumes[2-4] (1922, 1925, and 1928). The results of Wybergh's estimate of reserves are summarized in Table II.

Up to the time of the investigation by Wybergh, no geological survey of any coal-bearing areas had been undertaken, and it was only during 1935, when the Geological Survey was able to start on full-scale geological surveys of the more important coalfields, that more accurate figures for reserves could be determined.

Coal Commission: 1946–1947

This early work by the Geological Survey identified a potential shortage of coking coal, and on 10th June, 1946, the Governor-General of the Union of South Africa appointed a Coal Commission to report on measures to conserve the coking-coal resources of the Union of South Africa for coking purposes only, and to report on the standards of quality for coal for domestic use and for export. After due consideration, the Coal Commission interpreted the terms of reference of the Commission as being sufficiently broad to warrant obtaining a comprehensive view of the coal industry as a whole.

Prior to 1947, it was customary to speak of the 'inexhaustible' resources of coal in what is now the Republic of South Africa. This misconception arose from a failure to realize that the tonnage of coal in the ground and the tonnage of extractable coal are two vastly different figures. Apart from the measures outlined by the Coal Commission[6] to conserve coking coal for coking purposes only, the total tonnages of extractable coal can be deduced from scattered references in the 1946–1947 report as quoted by Petrick *et al.*[10] (p. 7) and summarized in Table III.

F.A. Venter: 1952

In the meantime, the Geological Survey, in close collaboration with the Fuel Research Institute, continued the systematic survey of South African coalfields. In 1952, F.A. Venter of the Fuels Branch of the Geological Survey chose as the topic for his Presidential Address to the Geological Society of South Africa 'Coal in the Union

TABLE II

COAL RESOURCES OF THE UNION OF SOUTH AFRICA (WYBERGH)[2-4]

(Quoted from *The Mineral Resources of the Union of South Africa*[5], 1940, p. 398)

Coal Fields.	PROVED. Cal. Val. over 12 lbs./lb. In short tons. *	Cal. Val. under 12 lbs./lb. In short tons. *	ESTIMATED In short tons.	UNDETERMINED In short tons. †	TOTAL In short tons.
Transvaal—					
Witbank	759,568,000	2,235,807,000	2,738,173,000	1,500,000,000	7,233,548,000
Springs–Heidelberg	–	344,839,000	2,818,000,000	8,107,744,000	11,270,583,000
Eastern Witbank	561,665,000	596,249,000	3,799,890,000	1,500,000,000	6,457,804,000
Bethal	–	–	–	7,508,000,000	7,508,000,000
Ermelo–Middelburg–Belfast	141,310,000	250,900,000	1,913,000,000	3,536,000,000	5,841,810,000
Piet Retief–Wakkerstroom	1,500,000,000	–	1,060,000,000	5,690,000,000	8,250,000,000
Springbok Flats	–	–	–	12,000,000,000	12,000,000,000
Waterberg	–	–	–	7,400,000,000	7,400,000,000
Zoutpansberg			No estimate possible		
Syferfontein No. 32	–	10,000,000	–	–	10,000,000
Komatipoort			No estimate possible		
Natal—					
Klip River	433,290,000	19,912,000	777,345,000	918,500,000	2,149,047,000
Vryheid	260,341,000	16,761,000	294,398,000	–	571,500,000
Utrecht	41,456,000	52,642,000	1,132,794,000	4,880,000,000	6,106,892,000
Orange Free State	–	1,500,350,000	471,900,000	150,000,000,000	151,972,250,000
Cape Province	Not estimated because of poor quality.				
UNION OF SOUTH AFRICA TOTALS	3,697,630,000	5,027,460,000	15,006,100,000	203,040,244,000	226,771,434,000

* Of the 'proved' coal in Natal 40 per cent, contains less than 16 per cent volatiles.

† See succeeding page.

TABLE III

EXTRACTABLE COAL

(In millions of short tons)

Area	Bituminous High-grade	Bituminous Medium and low grade	Blend	Coking	Anthracite	Total
Natal	381	–	–	164	60	605
Witbank–Middelburg	2 128	4 000	171	–	–	6 299
Breyten–Ermelo	217	235	–	–	–	452
Vereeniging	–	4 000	–	–	–	4 000
South Rand	–	800	–	–	–	800
Vierfontein	–	65	–	–	–	65
	2 726	9 100	171	164	60	12 221

of South Africa' and gave an overview of the geology and reserves of the various coalfields in South Africa[1]. The Republic's *in situ* coal reserves according to Venter were summarized by Van Rensburg *et al.*[9] (p. 11, Table IV) as shown here in Table IV.

Venter's figure for the total proved and probable reserves amounted to 74 872 million short tons—about one-third of Wybergh's original estimate of 226 771 million short tons, which, however, included 203 040 million short tons classified as undetermined.

Geological Survey: 1959

Seven years later, the State Geological Survey submitted other reserve figures for the coal deposits of the country[7] (p. 467, Table V). These are shown here in Table V.

Geological Survey (Bishopp: 1967)

Since the publication of the fourth edition of *Mineral Resources of the Union of South Africa* in 1959, considerably more information was obtained by private companies and by the Geological Survey and the Fuel Research Institute on the occurrences and reserves of South African coal. Thus, on the instruction of the Director of the Geological Survey, D.W. Bishopp prepared a memorandum[8] entitled 'Coal Resources of South Africa—Position at June 1967'.

Bishopp concluded as follows:

> 'On the basis of such incomplete information as we have at hand it seems probable that there is a reserve of at least 10 000 million tons of extractable, marketable coal which would meet existing requirements or specifications; and if full extraction of coal over 3 feet thick and calorific value about 9, were practised, at least three times that quantity. This, however is guesswork.'

The growing realization that the published figures for South Africa's coal reserves were out of date stressed the need for a detailed study of the country's usable coal reserves in relation to the anticipated demand.

Coal Advisory Board (Working Committee: 1967)

As a result of the above-mentioned developments, the Coal Advisory Board decided on 22nd June, 1967, that

TABLE IV

SOUTH AFRICA'S COAL RESERVES (QUOTED FROM VENTER[1], 1952)

[In millions of short tons *in situ*]

(1 short ton = 2000 lb = 907 185 kg)

(1 lb/lb = 2 257 MJ/kg)

Field	Average grade*	Proved reserves	Probable reserves	Total
Northern Witbank	12	500	–	500
Southern Witbank	12	3,500	3,500	7,000
Bethal	10 – 11	–	7,000	7,000
Breyten	11.5	900	–	900
Lake Chrissie–Carolina	11.5	150	–	150
Middelburg–Belfast	11.5 – 12	1,000	–	1,000
Springs	9	200	–	200
South-Rand	10	8,000	–	8,000
Ermelo–Piet Retief	11 – 12	5,150	11,000	16,150
Waterberg	11	2,140	12,000	14,140
Soutpansberg	10	–	5,000	5,000
Springbok Flats	–	–	10,000	10,000
Northern Natal	12.5 – 13	415 (bituminous)	–	–
		233 (anthracite)		648
Klip River	–	440	1,710	2,150
Vereeniging–Clydesdale	9.5	828	–	828
Vierfontein–Odendaalsrus	10	181	1,025	1,206
Total Transvaal	–	–	–	70,040
Total Natal	–	–	–	2,798
Total Orange Free State	–	–	–	2,034
Grand total for Republic		–	–	74,872

*In lb/lb

detailed information on the *in situ* reserves of extractable coal in the Republic in all categories, related to the various uses of coal, had to be collected. A working committee, consisting of one representative each from the Department of Planning (W.C.J. van Rensburg), the Geological Survey (D.W. Bishopp), and the Fuel Research Institute (W.H.D. Savage) was appointed to carry out this task.

The working committee decided to divide the total resources of coal into three categories (Van Rensburg *et al.*[9], p. 14):

(i) *Reserves of coal*
The reserves of coal included coal in existing commercial mines, in captive collieries, and in prospected areas in the then (1967) exploited coalfields of the Republic.

(ii) *Potential reserves of coal*
By definition, the reserves included in this section were not at the time considered to be economically extractable owing, *inter alia*, to the absence of the necessary economic infrastructure, other mining operations, a lack of suitable markets, and promising but unproved mining methods (p. 17).

(iii) *Other resources of coal*
Coal included under this heading was not regarded as economically extractable then or in the then foreseeable future because of poor quality, depth of occurrence, depletion of reserves, broken-up nature due to faulting and folding, or the thinness of the seams.

The total reserves and resources of coal *in situ* as determined by the Working Committee of the Coal Advisory Board were summarized by Petrick *et al.*[10] (p. 38).

Commission of Inquiry (Petrick Report): 1975

The report by the Working Committee of the Coal Advisory Board (Van Rensburg *et al.*[9]) indicated that, according to the information available at the time, the Republic's coal reserves would be seriously depleted, if not totally exhausted, within 40 to 100 years. Concern over this alarming prospect led to the appointment of the Petrick Commission[10] (A.J. Petrick, W.C.J. van Rensburg, and A.D. Vos) by the State President on 22nd May, 1970.

The basic approach of the Petrick Commission to the classification of coal reserves and resources is similar to that of the 1969 estimate by Van Rensburg *et al.* for the Coal Advisory Board, but is based on far more detailed information, and it highlights the need for clear definitions of all the concepts as summarized by Petrick *et al.*[10] (Table 5.3/1, p. 46) and quoted here as Table VI.

The total coal resources of the Republic of South Africa, according to Petrick *et al.*[10] (Table 5.3/2, p. 47), are re-arranged in Table VII per coalfield, coal type, and mining method so that they can be compared with De Jager's reserves.

Geological Survey—F.S.J. de Jager: 1982

In an interim report to the Government by the Geological Survey (May 1981), the *in situ* mineable reserve of bituminous coal was given as 110 000 Mt and the recoverable portion as 51 000 Mt. These results formed the basis on which the Government, during May 1981, allocated 80 Mt per year for export over the next 30 years (De Jager[11], p. 91).

The most recent assessment of coal reserves for the Republic was made by the Geological Survey and published as *Bulletin* 74 (Coal Reserves of the Republic of South Africa—An Evaluation at the End of 1982, by F.S.J. de Jager[11]). A summary of this evaluation is given here in Table VIII.

This evaluation was made in very close co-operation with the mining industry. Data were collected relating respectively to bituminous, metallurgical, and anthracitic coal (Addenda A, B, and C), and this information was used to build a temporary coal data-bank for assessment of the coal reserves of the Republic of South Africa. An undertaking was given to the mining industry by the Geological Survey that this temporary data-bank would be used only for the assessment of reserves and would then afterwards be destroyed to guarantee confidentiality. Mining and prospecting companies evaluated their individual reserve blocks separately, each company according to its own standards and policy. Information on a total of 964 reserve blocks was thus submitted, unfor-

TABLE V

COAL DEPOSITS OF SOUTH AFRICA[7]

(1 short ton = 2000 lb = 907,185 kg)

(1 lb/lb = 2,257 MJ/kg)

Province and Coal-field	Approx. C.V. in lb./lb.	Proved reserves in millions of short tons	Probable reserves in millions of short tons	Total
I. TRANSVAAL:				
1. Springs–South Rand	10	8,200	—	8,200
2. Witbank	12	4,100	3,500	7,600
3. Bethal	11	—	7,000	7,000
4. Middelburg–Belfast and Eastern Witbank	11.5—12	1,000	—	1,000
5. Breyton, Ermelo–Piet Retief	12	6,200	11,000	17,200
6. Springbok Flats	10	—	5,000	5,000
7. Waterberg	12	17,500	—	17,500
8. Soutpansberg	12	—	5,000	5,000
9. Vereeniging	10	184	—	184
Total (Transvaal) ...		37,184	31,500	68,684
II. NATAL:				
1. Kliprivier	12.5	440	1,710	2,150
2. Vryheid	13	170	—	170
3. Utrecht	12.5	478	—	478
Total (Natal)		1,088	1,710	2,798
III. ORANGE FREE STATE:				
1. Vierfontein	10.5	181	—	181
2. Odendaalsrus	10	—	1,025	1,025
3. Vereeniging	10	2,194	—	2,194
Total (O.F.S.)		2,375	1,025	3,300
IV. CAPE PROVINCE	11	—	5,000 (not exploitable)	5,000
GRAND TOTAL, UNION OF SOUTH AFRICA		40,647	39,235	79,882

tunately without a formal record of the basis of assessment in each case. However, De Jager collected all the completed data forms (Addenda A, B, and C) personally from each contributor. The basis for the extractable figure for every block or combination of two or more blocks was explained to him. In certain isolated cases, particularly for big consolidated *in situ* tonnages, important changes were brought about by agreement or at De Jager's insistence[12].

The 1982 coal reserve therefore embraces the sum total of the reserves in the coal portfolios of the coal-mining and prospecting companies as supplied by them, except for the Waterberg field, parts of the Soutpansberg field, the Springbok Flats field, and small areas within certain other fields of the traditional coal-mining areas (De Jager[11], p. 4). These latter areas were assessed independently by the Geological Survey.

The companies submitted proven or indicated reserves of all the blocks or areas of coal held by them. The proven reserves indicated coal occurrences for which quantities and qualities could be measured with a high degree of certainty and which could be legally extracted at the time of determination. Indicated reserves referred to coal occurrences for which estimates of the quality and quantity could be computed partly from their distribution (from rather limited sample analyses) and partly from reasonable geological projectioning. Unfortunately, these parameters were not quantified and recorded.

Only a rather small percentage of the reserve fell in the indicated category for this assessment, so that it could be lumped together with the proven reserves in the summation of quantities within certain quality or rank categories (De Jager[11], p. 4).

For the Upper Ecca (Beaufort Group according to De Jager) consisting of interbedded coal and mudstone in the Waterberg Coalfield, De Jager stipulated a minimum and maximum mining height of 2,0 and 3,5 m respectively, and a minimum clean-coal thickness of around 1 m in the selected mining width to qualify as *in situ* mineable. This implies that an '*in situ* beneficiation' was resorted to by excluding the thicker and well-defined beds of carbonaceous mudstone from the calculations. The yields obtained by such '*in situ* beneficiation' were, unfortunately, not recorded.

The total coal reserves of the Republic of South Africa as determined by De Jager are summarized here in Table

TABLE VI

DESCRIPTIONS AND SPECIFICATIONS USED IN THE REPORT BY PETRICK *ET AL.*[10]

Reliability	Number of Boreholes or Adits per 2000 ha		
	Proven: more than	Indicated: from-to	Inferred: fewer than
Waterberg	8	7 – 3	2
South Rand	10	9 – 3	2
Springfield: Western Area Limpopo: Springbok Flats Soutpansberg	10	9 – 5	4
Molteno-Indwe S.W.A. Gibeon: S.W.A. Ovambo O.F.S.-Vierfontein Vereeniging–Sasolburg Witbank Seams 2, 4A & 4 Up Highveld Seams 2, 4 & 5 Pafuri	10	9 – 3	2
Eastern Transvaal: Utrecht Kliprivier: Vryheid: Zululand	20	19 – 5	4
Komatipoort	30	29 – 5	4
Witbank Seams 1, 3 & 5 Highveld Seams 1 & 3	30	29 – 10	9

Specifications for Mineable Coal *in situ* (b) (c)						
Type of (a) Coal		Bituminous				Anthracitic coal (washed)
		Raw	Washed			
Factor	Local name	Low grade steam coal	High grade steam coal	Metal-lurgical coal		Anthracitic coal
	Symbol	Lgsc	Hgsc	Metl		Anth
Depth (metres)	Max Min	300 15	400 15	500 15		500 15
Workable thickness (metres)	Max Min	6 1,2	6 1,2	6 0,7		6 0,7
Minimum yield at S.G.		Raw	70% 1,6	50% 1,4		60% 1,6
Ash	Max	35%	17%	14%		15%
Dry Ash-free Volatiles	Max Min	– 16%	– 16%	– 16%		14% 8%
Swelling Index	Min	–	–	2		–

Specifications for extractable coal (d)						
Factor		Type of coal	Lgsc	Hgsc	Metl	Anth
Control file number			010020	010007	010017	010016
Underground	Minimum (e) metric tons mineable *in situ*	Raw	150	–	–	–
		(f)	–	30	3	2
	Range of depth	Metres	15 – 300	15 – 400	15 – 500	15 – 500
	Range of thickness	Metres	1,2 – 6,0	1,2 – 6,0	0,7 – 6,0	0,7 – 6,0
	Extraction % (a mining loss of 10% has been deducted)		Bord and pillar Salamon formula	As for lgsc to 200m then 85%	15 – 100m bord and pillar then 85%	85%
Open cast (includes coal left in pillars)	Minimum tonnage (e)		As for underground mining			
	Depth (metres)		0 – 15	15 – 50	50 – 500	
	Extraction		90% throughout			
	Seam thickness		Not critical			
	Stripping ratio m³ overburden to m³ mineable coal		Up to 5:1	Up to 10:1	Up to 15:1	

Priority for the extraction of coal seams which are likely to be close together						
Coalfield		First	Second	Third	Fourth	Fifth
Limpopo		Bottom	Top	–	–	–
Waterberg		7	6B	5B	3	2
Pafuri		2	1	–	–	–
Witbank		2	1	4	–	–
Highveld		4	4 up	–	–	–
Eastern Transvaal	Except Davel	C up	C	–	–	–
	Davel only	C lo	C up			
Komatipoort		K3A	K3B	–	–	–
South Rand		Main Bottom	Main Middle	Main Top	–	–
Old Springfield		2A	2B	1	–	–
Vereeniging–Sasolburg		2A	2B	1	–	–
O.F.S. Vierfontein		Bottom	–	–	–	–
Utrecht		Moss	Main	Yard	–	–
Klipriver		Bottom	Top	–	–	–
Vryheid		Gus	Dundas lower	Dundas upper	–	–
Zululand		Middle	Lower	–	–	–
S.W.A. Gibeon		Lower B	–	–	–	–

Notes

(a) Coal is a carbonaceous rock of sedimentary origin containing not more than 50% of ash.

(b) Coal *in situ* is the total amount of coal in a given area occurring in its natural environment; since it includes all coal, however deep or thin it may be, this is an academic figure, which will not be published.

(c) Mineable coal *in situ* is that portion of the coal *in situ* which can be mined by existing techniques.

(d) Extractable coal is that portion of the mineable coal *in situ* which is extractable in prevailing or slightly less rigorous economic conditions.

(e) Minimum tonnage means the smallest tonnage which will make an isolated property a viable proposition; but two or more smaller properties within 5 km of each other and making up the required tonnage are admissable.

(f) Washery discards allowed for.

TABLE VII

COAL RESOURCES (PETRICK *ET AL.*[10])

(In megatons)

Coalfield	*In situ* mineable					Extractable by underground mining				Extractable by opencast mining			
	15–400 m	Raw bit.*	Washed bit.	Met. (Washed)	Anthr. (Washed)	Raw bit.	Washed bit.	Met. (Washed)	Anthr. (Washed)	Raw bit.	Washed bit.	Met. (Washed)	Anthr. (Washed)
Witbank	17 295	17 294	7 251	280	–	8 081	3 711	169	–	15 091	5 363	109	–
Highveld	25 407	25 407	10 540	82	6	9 913	4 443	–	5	6 775	2 050	–	–
South Rand	3 119	3 118	461	–	–	750	53	–	–	–	–	–	–
Springbok Flats	1 653	1 653	–	–	–	–	–	–	–	–	–	–	–
Waterberg Upper Lower	26 137	17 915	3 175	2 287	–	2 369	727	319	–	4 151	79	–	–
Limpopo	1 292	517	–	243	–	237	–	–	–	392	–	–	–
Soutpansberg	584	497	–	13	–	160	–	–	–	–	–	–	–
Western Areas	26	26	–	–	–	–	–	–	–	–	–	–	–
Utrecht	882	804	209	194	313	167	70	39	132	170	59	12	32
Klip River	2 339	1 668	498	133	188	465	162	88	76	137	3	–	–
Vryheid	168	167	115	98	62	91	78	53	28	17	20	3	–
Eastern Transvaal	5 610	5 468	2 582	121	175	1 471	1 212	37	134	1 056	363	–	–
KwaZulu	12	12	–	–	–	–	–	–	–	–	–	–	–
Kangwane	–	–	–	–	–	–	–	–	–	–	–	–	–
Sasolburg–Vereeniging	6 245	6 244	8	–	–	1 029	6	–	–	605	–	–	–
Orange Free State (Remainder)	870	425	–	–	–	236	–	–	–	–	–	–	–
Old Springfield Coalfields	59	59	52	–	–	–	–	–	–	–	–	–	–
Total	91 698	81 274	24 891	3 451	744	24 969	10 462	705	375	28 394	7 937	124	32

bit. = bituminous met. = metallurgical anthr. = anthracite or anthracitic

*Contains the washed bituminous coal and the metallurgical coal

VIII under the headings bituminous, metallurgical, and anthracitic coal, the lastmentioned being further subdivided into anthracite and lean coal. Reserves for each of these coal types are then subdivided into *in situ* mineable, recoverable, and saleable high-grade or 'recoverable beneficiation assumed'.

Comparison of the Two Latest Reserve Figures

Being the most recent information available, the reserve figures arrived at by De Jager[11] and Petrick *et al.*[10] are summarized and compared in Table IX.

A comparison of Petrick's and De Jager's information is complicated by the fact that De Jager decided to use a different basis from that used by Petrick and did not define his assumptions. A quantitative reconciliation of the two sets of figures is difficult, for three main reasons.

(1) Petrick's basis of assessment is well-defined but rather arbitrary, and is probably less stringent than the parameters laid down by mining and prospecting companies for their own use and submitted as such for De Jager's assessment. These parameters applied by De Jager for the 964 reserve blocks could, unfortunately, not be recorded for reasons of confidentiality. However, the high quality of information submitted by the mining companies is evident from examples of Forms 1, 2, and 3, which pertain respectively to bituminous coal, metallurgical coal, and anthracitic coal (Addenda A, B, and C).

(2) During the period 1975–1982, a vast amount of exploration was done, and this new information was used by mining companies to update their reserve figures for De Jager's assessment.

(3) Coal classified by Petrick as extractable by underground mining cannot be added to coal extractable by opencast mining, i.e. Petrick probably allowed for coal unextractable by underground mining at shallow depths in cases where such coal will be mined by opencast methods at a much higher extraction factor. De Jager, on the other hand, did not refer to underground and opencast mining separately.

Owing to the vast amount of exploration carried out since the Petrick report[10] (1975), De Jager[11] (1982) could report a total of 113 326 Mt for *in situ* mineable bituminous coal, as against Petrick's 81 274 Mt (Table IX).

A comparison between the recoverable reserves as determined by Petrick *et al.* (1975) and by De Jager (1982) indicates an increase in recoverable reserves of raw bituminous coal of 32 172 Mt (126,8 per cent).

Gains and losses on Petrick's inferred reserves occurred, but from Table IX it is obvious that the increase in reserves of *in situ* mineable bituminous coal from 81 274 Mt (Petrick) to 113 326 Mt (De Jager) is largely due to De Jager's figure of 49 923 Mt for the Waterberg

TABLE VIII
COAL RESERVES: AFTER DE JAGER[11] (1982)
(In megatons)

	Bituminous coal		Metallurgical bituminous coal			Anthracitic coal					
						Anthracite			Lean coal		
Coalfield	*In situ* mineable	Recover-able	Saleable* high grade	*In situ* mineable containing met. coal	Recover-able benefi-ciated	*In situ* mineable	Recover-able	Recover-able bene-ficiated	*In situ* mineable	Recover-able	Recover-able bene-ficiated
Witbank	16 241,17	12 460,96	6 455,28	1 839,53	400,88	–	–	–	–	–	–
Highveld	16 909,43	10 979,03	1 513,12	567,20	230,57	–	–	–	–	–	–
South Rand	3 072,10	730,10	–	–	–	–	–	–	–	–	–
Springbok Flats	3 250,00†	1 700,00	1 700,00	1 050,00	150,00	–	–	–	–	–	–
Waterberg Upper	23 303,00	18 000,00	3 000,00	Substantial	Substantial	–	–	–	–	–	–
Lower	26 620,00		1 883,00	–	–	–	–	–	–	–	–
Limpopo	256,00	202,00	107,00	256,00	107,00	–	–	–	–	–	–
Soutpansberg‡	1 450,00	725,00	267,00	1 450,00	1 267,00	–	–	–	–	–	–
Western Areas	–	–		–	–	–	–	–	–	–	–
Utrecht	749,54	510,78	316,43	202,00	102,00	–	–	–	–	–	–
Klip River	705,38	471,62	314,12	462,00	158,00	1 082,27§	711,65§	475,70§	395,36§	266,02§	141,62§
Vryheid	86,57	70,63	55,58	86,00	39,00	–	–	–	–	–	–
Eastern Transvaal	7 052,85	4 538,10	2 450,66	29,80	16,14	–	–	–	–	–	–
KwaZulu	–	–	–	–	–	256,75	172,83	98,68	Nil	Nil	Nil
Kangwane	–	–	–	–	–	467,00	227,50	147,10	Nil	Nil	Nil
Sasolburg–Vereeniging	4 757,10	2 233,32	–	–	–	–	–	–	–	–	–
Orange Free State	–	–	–	–	–	–	–	–	–	–	–
Remainder	8 876,00	4 919,60	–	–	–	–	–	–	–	–	–
Old Springfield	–	–	–	–	–	–	–	–	–	–	–
Total	113 329,14	57 541,14	18 062,19	5 942,53	1 470,59	1 806,02	1 111,98	721,48	395,36	266,02	141,62

* Included in recoverable

† For the Springbok Flats, *in situ* beneficiated mineable product (a 50% factor) was calculated, 60% mining yield (extractability) assumed, and a total of 250 Mt mining loss (i.e. geological loss) allowed for

‡ Republic of Venda excluded

§ Total for Utrecht, Klip River, Vryheid, and Eastern Transvaal

Coalfield, as against Petrick's figure of 17 915 Mt. This means that, according to De Jager, 44 per cent of the *in situ* mineable reserves of bituminous coal occur in the Waterberg coalfield. The question is whether this *trebling of reserves is due to a change in approach or to increased exploration activity in South African coalfields during the period 1975–1982.*

The answer is that, during the period 1975 to 1982, extensive exploration was carried out in the Waterberg Coalfield, and mining companies could supply much more information for De Jager's assessment than was available to Petrick in 1975. De Jager also had the advantage of a reliable correlation of coal seams in the upper bright-coal zones of the Waterberg Coalfield based on detailed work by mining companies.

The gains and losses resulting in the net increase of 32 052 Mt of *in situ* mineable reserves (Table IX) are summarized in Table X, with explanatory notes in the 'Remarks' column. The increase in the *in situ* mineable reserves of 32 008 Mt in the Waterberg Coalfield is mainly responsible for the net increase, while the contribution of 8 451 Mt from the OFS compensates for the loss of 8 498 Mt in the Highveld Coalfield.

A comparison of Petrick's and De Jager's recoverable reserve figures shows an increase in recoverable reserves of raw bituminous coal of 32 172 Mt (126,8 per cent) above the 25 369 Mt of the Petrick report (Table XI). This is a significant increase and is mainly attributable to an increase of 15 631 Mt in the Waterberg Coalfield.

Reasons for Differences between Reserve Estimates

In an attempt to reconcile the terms of reference of the different investigators, the different estimates and assumptions were examined against the milieu in which each of the estimates was undertaken. The main reasons for differences were found to be as follows.

(i) *Background and objectives of reserve estimates*: The different reserve estimates were made against different backgrounds and were based on different assumptions. The terms of reference according to which the investigators had to operate were determined by the exigencies of the times.

(ii) *The inclusion of different coalfields*: All the estimates did not include the same coalfields owing to different approaches towards the adequacy of the exploration and the availability of data.

(iii) *Increase in geological information*: The inclusion or otherwise of individual coalfields was determined mainly by the availability of reliable geological information. More extensive exploitation and exploration continuously provide more information, and reserves should be reviewed as dynamic.

(iv) *Division and classification of reserves*: Different types and grades of coal were reported by different workers.

(v) *Economic factors*: Since coal reserves are of value only if they are economically exploitable now or in the immediate future, it is important that reserves

TABLE IX
IN SITU MINEABLE BITUMINOUS COAL PER COALFIELD ACCORDING TO PETRICK[10] AND DE JAGER[11]

	Petrick, Mt				De Jager Mt	Change Mt
	Proven	Indicated	Inferred	Total		
Witbank	14 186	1 985	1 123	17 294	16 241	−1 053
Highveld	7 231	13 181	4 995	25 407	16 909	−8 498
South Rand	600	2 518	–	3 118	3 072	−46
Springbok Flats	0	0	1 653	1 653	3 250	+1 597
Waterberg Upper / Lower	6 386	1 778	9 751	17 915	49 923	+32 008
Limpopo	517	0	0	517	256	−261
Soutpansberg	–	347	150	497	1 450	+953
Western Areas	0	26	0	26	0	−26
Utrecht	120	236	448	804	749	−55
Klip River	748	204	715	1 668	705	−963
Vryheid	141	2	24	167	86	−81
E. Transvaal	805	3 111	1 552	5 468	7 052	+1 584
KwaZulu	0	0	12	12	0	−12
Kangwane	–	–	–	0	0	0
Sasolburg–Vereeniging	1 233	2 411	2 601	6 244	4 757	−1 487
OFS (remainder)	197	228	0	425	8 876	+8 451
Old Springfield	59	–	0	59	0	−59
	32 223	26 027	23 024	81 274	113 326	+32 052
Minus Waterberg				17 915	49 923	+32 008
				63 359	63 403	+44

TABLE X
INCREASE IN *IN SITU* MINEABLE RESERVES
[De Jager (1982) versus Petrick (1975)]

Field	Increase Mt	Remarks
Springbok Flats	+1 700	New information obtained
Waterberg	+32 008	New information obtained
Soutpansberg	+953	New information obtained
Eastern Transvaal	+1 584	More detailed information available
Orange Free State	+8 451	New information obtained
Total	+44 593	
	Decrease Mt	
Witbank	−1 053	More detailed information available
Highveld	−8 498	More detailed information available
Limpopo	−261	New information obtained
Klip River	−963	New information obtained
Vereeniging	−1 487	New information obtained
Other fields	−279	New information obtained
Total	−12 541	
Grand total	+32 052	

should be calculated on this basis. Petrick[10] (p. 37) regarded *reserves* as 'economically exploitable deposits of which the magnitudes are known within definite limits' and *resources* as simply denoting 'known occurrences of coal, where the magnitudes of the deposits and their economic exploitability are either not known or are such that exploitation is not warranted at present'.

In his determination of extractable coal, Petrick used the following standard: 'Extractable coal is that portion of the mineable coal *in situ* which is extractable in prevailing or slightly less rigorous economic conditions'.

In his report, De Jager[11] used the term 'extractable pithead product' and qualified it in certain cases by stating that 'beneficiation' is 'assumed', but he did not indicate clearly whether all his reserves were economically recoverable under current economic conditions.

The Case for Reliable Reserve Figures

Since coal is South Africa's most important source of energy, and will remain so for some time, the need for reliable figures on its reserves of economically recoverable coal is self-evident. The energy crisis of 1974 caused a great increase in the world's demand for coal for the generation of energy, which makes reliable figures on reserves even more essential to ensure that internal demands will be met at all times. Exports must therefore be planned with this in mind.

Petrick made the following very apt remark in this connection:

Resources and reserves

One of the main reasons for the general air of optimism regarding our coal reserves in the past was undoubtedly that the most recent reports on 'coal reserves' were taken at their face value, whereas in most cases the precise meanings of the terms used were not defined.

There is confusion about the definition of terms such as 'reserves' and 'resources'. For instance, during the past decade estimates of the coal mineable in the United States at prevailing prices have ranged

TABLE XI

RECOVERABLE COAL PER COALFIELD ACCORDING TO PETRICK (1975) AND DE JAGER (1982)

(In megatons)

	Raw bituminous		Saleable high-grade washed bituminous		Metallurgical washed		Anthracitic washed	
	Petrick	De Jager	Petrick	De Jager	Petrick	De Jager	Petrick	De Jager
Witbank	8 464*	12 461	3 800*	6 455	169	400	–	–
Highveld	9 913	10 979	4 443	1 513	–	230	5	–
South Rand	750	730	53	–	–	–	–	–
Springbok Flats	–	1 700	–	1 700	–	150	–	–
Waterberg Upper / Lower	2 369	18 000	727	4 883	319	Substantial	–	–
Limpopo	237	202	–	107	–	107	–	–
Soutpansberg	160	725	–	267	–	267	–	–
Western Areas	–	–	–	–	–	–	–	–
Utrecht	167	510	70	316	39	102	132	–
Klip River	491	472	162	314	88	158	76	617
Vryheid	93*	71	83*	55	54*	39	28	
Eastern Transvaal	1 460*	4 538	1 222*	2 450	37	16	134	
KwaZulu	–	–	–	–	–	–	–	98
Kangwane	–	–	–	–	–	–	–	147
Sasolburg–Vereeniging	1 029	2 233	6	–	–	–	–	–
OFS (remainder)	236	4 920	–	–	–	–	–	–
Old Springfield	–	–	–	–	–	–	–	
	25 369	57 541	10 566	18 060	706	1 469	375	862
Increase (De Jager)	+32 172 / +126,8%		7 494 / +70,9%		763 / +108,1%		487 / +129,9%	

* Opencastable coal (0 to 15 m) added to extractable underground (deeper than 15 m)

from 20 to 380 billion tons. It is clear that the higher figures do not describe the same concept as the lower ones, emphasizing the point that: '. . . if we do not know what the figures really mean, they are not merely useless; they are worse than useless, because they tend to mislead'.

Despite this confusion several reputable organisations in South Africa and overseas have used estimates of energy 'reserves' as key elements in their forecasts of future production of various energy-carriers, without attempting to assess the accuracy of these estimates or appreciating that such 'reserves' are dynamic and that there are significant variations in the quality of the various elements which constitute our national coal resources.

A heavy demand for coal export permits thus compelled the State to put the available figures on reserves above suspicion in order to eliminate risky decisions. The results of the Petrick Commission basically indicated that South Africa should use its coal reserves carefully. Considerable pressure was exerted by mining entrepreneurs who regarded these figures as extremely conservative, and it became necessary to check the figures once more. This task was given to the Geological Survey.

The pressure to which the State was subjected is clearly illustrated in the paper by R.E. Burnton entitled 'Coal as a Source of Energy', which was read at the 1820 Settlers National Monument Foundation Conference in 1978. In his concluding paragraphs he stated, *inter alia*:

The Case for Coal Exports

It is necessary to refer to this problem in relation to our energy inventory and future coal based energy needs. There has been unease amongst certain people at the increasing rates of coal exports. Exports have become a contentious subject on several grounds, most of which have a high emotional content, and express the belief that the conservation of resources for the future is an overriding end in itself. These arguments are:

(i) Why export our best coal when the reserves are stated to be limited?
(ii) We are selling our birthright for a mess of potage.
(iii) Our coal resources form part of a capital resource which belongs to our children as well as to us. We should conserve our precious energy resources instead of shipping them to foreigners.

Exports require a higher calorific value coal due to transport costs. It has previously been shown that South Africa has adequate reserves of high calorific value coal, and that the envisaged export levels have a very minor influence on the life of these reserves.

There is thus a very strong case for exports based on the following grounds:

(i) The export earnings, free on board ship, are about four to five times as great as the price currently paid for coal used locally for power generation purposes, and about three times as great as the price paid by the general inland market. The viability of the local industry would indeed be in doubt were it not for these export earnings.
(ii) Without discounting the future it must be accepted that our country must somehow now earn the foreign currency it needs to pay for the imported capital goods which will generate its future energy and, indeed for the increasing oil import bill.
(iii) Energy is a problem for the free world. The fact that South Africa can become a reliable supplier of what it has to offer will strengthen our strategic position, and also help to justify our claim on oil supplies from other countries. Isolation from the international trade would be a sure path to political isolation.
(iv) The production of say 40 million tons of coal creates job opportunities for about 15 000 people at the collieries alone. At least a similar amount of job opportunities will be created in the supply and infrastructure industries. The need for the creation of job opportunities need hardly be stressed.

Surely then the above observations are more than adequate to not only motivate a case for exports, but indeed underscore the need for exports.

An interim report to the Government by the Geological Survey (May 1981) claimed a significant increase in reserves, which in turn led to the following comment in the 'Coal Survey—A Survey Supplement to *Financial Mail*', 14th August, 1981:

> Simultaneously another study by the department in conjunction with the Geological Survey has more than doubled SA's economically extractable reserves of bituminous coal. The Petrick Report put these at 25 000 million tons; now they're 51 000 million tons.
>
> Total reserves have been raised from Petrick's 81 000 million tons to 110 000 million tons. *Minister of Mineral and Energy Affairs Frederick de Klerk says the figures are 'a conservative minimum'.*
>
> The total reserves do not yet include deposits inferred between known reserves.
>
> *Mineable reserves, in the view of experts outside government—like Professor Richard Dutkiewicz of UCT's Energy Research Institute—could have been set at 60 000 million tons or more.* They reason that better prices and technology have made a higher figure realistic.

The end result of the whole action was that, on 4th September, 1981, the Minister of Mineral and Energy Affairs announced the following decision by the State:

> In the first place, certain decisions have been taken about coal exports. The Government has decided to increase the present level of coal exports to 80 million tons a year for 30 years, to be constituted as follows:
>
> (a) The already approved maximum level of 44 million tons a year for 30 years, i.e. 1320 million tons in all.
> (b) An additional 32 million tons a year for 30 years, i.e. 960 million tons in all. That is what has now been decided on.
> (c) A further 4 million tons a year, which has already been authorised in the past, for shorter periods. It is envisaged that these 4 million tons will also be placed on a firmer basis.
>
> In all, these three components amount to 2400 million tons of coal over 30 years (Hansard, column 2985, 4/9/81).

In view of the fact that the volume of economic recoverable reserves is influenced by various external factors, such reserves cannot be regarded as being fixed, but rather dynamic, and regular updating is essential. After such updating, all decisions could be reconsidered and consequential adjustments to planning could be timeously made.

It must be determined whether *the figures for the coal reserve given by F.S.J. de Jager*[11] are correct. The reliability of these figures is of extreme importance, since the policy- and decision-makers largely use this information when they are confronted with suggestions made by entrepreneurs in the utilization of this resource. The information must therefore be correct, and the following aspects must be considered in an evaluation.

(i) An additional risk in decision-making is the fact that all coal in the ground is not necessarily available coal; it is therefore essential that the *in situ* reserves be properly classified. The application of the additional *in situ* mineable reserves of 8451 Mt in the OFS (Tables X and XI) is very limited owing to the quality of this coal, whereas the coal sources of the Witbank, Highveld, and eastern Transvaal areas have a much broader application. The country's own needs for different grades of coal must be taken into account when decisions are taken.

(ii) The correctness of the recoverable reserve figures is determined mainly by the extraction percentage used in planning. This percentage is a function, *inter alia*, of a decision as to which of the coal seams in a multi-seam coal deposit that can be mined by underground mining methods are to be exploited first.

(iii) The geographical position of the coal occurrence, its extent, and the availability of infrastructure have a significant influence on the exploitability of such an occurrence. This is exemplified by the Limpopo Coalfield, where the infrastructure and application potential are almost completely lacking.

(iv) The delivered selling price of all the grades of coal probably has the greatest influence on the exploitability of an occurrence. The selling price, in turn, is decisively influenced by the costs of mining, beneficiation, yield, and transport. The transport cost varies as follows according to tariff book rates and contract rates:

Tariff book rate	R0,053 to R0,079 per ton per kilometre
Contract rate	R0,0423 to R0,055 per ton per kilometre.

The cost of transporting 1 ton of coal from the Waterberg Coalfield to Richards Bay will therefore be about R55,226 (1042 km × R0,053). This obviously determines the feasibility of exporting coal from this field.

In order to find an answer to this question, I investigated the reserves of three coalfields that are well-known to Iscor, namely Waterberg, Soutpansberg, and Natal, and compared these results with those of De Jager.

The Waterberg Coalfield

In view of the fact that the Waterberg Coalfield is the major contributor to the total coal reserves of the Republic of South Africa, the reliability of reserve figures for this field is of vital importance.

The coal seams of the Waterberg Coalfield (Fig. 1) occur in the Middle and Upper Ecca Group of the Karoo Sequence. The Middle Ecca coal (zones 1, 2, 3, 4A, and 4 from the bottom to the top) occurs in a mainly sandy succession about 42 m thick. Zone 2 varies in thickness from 1,0 to 4,5 m in the western shallow area of the coalfield and is usually thicker (up to 5,2 m) in the central deep area. Zone 3 is up to 9 m thick in the central deep part, where it contains much intercalated mudstone, but thins out to less than 1 m in the northwestern part. The coal of zones 1 to 4 in both areas consists mainly of dull coal with bright coal only in the bottom 1 or 2 m. Zones 2 and 3 are separated by 5 m of sandstone. The other zones (1, 4, and 4A) are economically of minor importance (De Jager, pp. 320–321).

The Upper Ecca coal is a typical multi-seam deposit consisting of coal beds varying in thickness from a few centimetres to just more than 1 m, intimately interbedded with mudstone over a total thickness of about 60 m. Seven prominent zones (5 to 11 from the bottom to the top) of cyclical sedimentation are clearly observable. The bottom parts of each of the seven zones consist mainly of bright coal, which is gradually replaced by mudstone higher up, so that the topmost part of each zone consists mainly of mudstone, with the exception of zone 11, where the topmost part consists of a thin but persistent layer of coal. Coal, *per se*, constitutes about 33 per cent of the total thickness of the Upper Ecca Group.

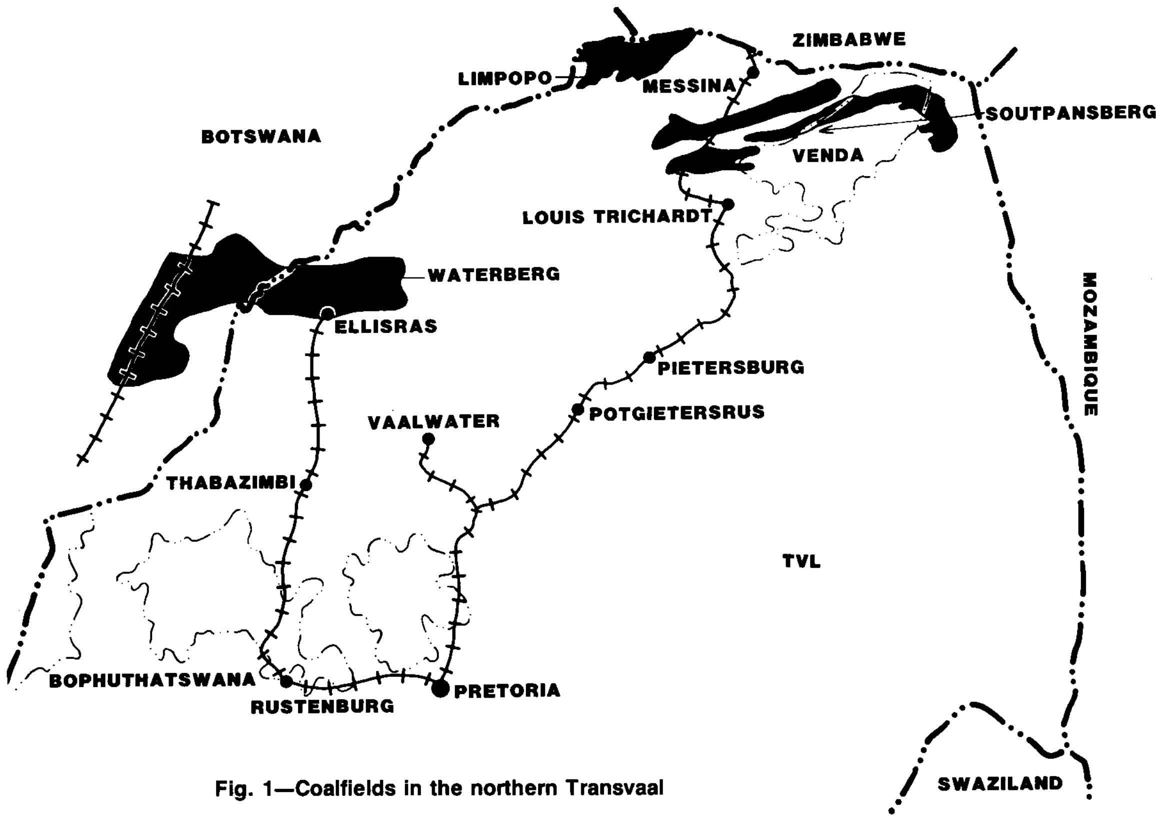

Fig. 1—Coalfields in the northern Transvaal

Over the past three decades, Sasol and Iscor have carried out extensive exploration and research programmes on the portion of the Waterberg Coalfield reserved by the State for the petrochemical and metallurgical industries. A vast number of coal samples have been taken. By 1985, approximately 930 boreholes had been completed, comprising a total of 106 000 m, and the total cost of exploration had amounted to R45 million (1985 value).

Outside this reserved area, several mining companies have also conducted intensive exploration programmes. Iscor established the Grootegeluk Mine in 1979 to produce blend coking coal for Iscor and a middlings fraction, obtained from the beneficiation process, for use by Escom in the Matimba power station. At present, the Grootegeluk Mine supplies 35 per cent of the coking coal used in Iscor's coking blends, and can meet the present and future coal requirements of the Matimba power station.

At the time when the Petrick Commission was appointed by the State President (22nd May, 1970), much less information regarding the Waterberg Coalfield was available to the Commission than was available to the Geological Survey (De Jager) in 1982. At present (1987), still more information is available.

Taking into account that, according to De Jager's findings, 49 923 Mt (44 per cent) of the Republic's *in situ* mineable reserves of bituminous coal (113 326 Mt) occur in the Waterberg Coalfield, it is time to have another look at the state of the reserve with due consideration of all the coal-related developments and changes since 1982. This re-appraisal should be made with appreciation for the work carried out by De Jager, and also for the tremendous contribution made by the Geological Survey to mining in the Republic of South Africa.

The Waterberg Coalfield consists of an area where the coal is relatively near the surface and available for opencast mining methods, and a portion of the field where the coal is relatively deep and will have to be mined by underground mining methods.

In Situ Coal Reserves

Table XII shows the *in situ* reserves of the Waterberg Coalfield based on the latest information.

TABLE XII
COAL RESERVES (RAW COAL *IN SITU**) IN THE WATERBERG COALFIELD
(In megatons)

		Bright coal	Dull coal	Total
Opencastable†:	State area‡	11 095	7 410	18 505
	Other§	12 959	2 814	15 773
	Total	24 054	10 224	34 278
Deep coal:	State area	30 039	4 839	34 878
	Other	12 178	5 213	17 391
	Total	42 217	10 052	52 269
Total:	State area	41 134	12 249	53 383
	Other	25 137	8 027	33 164
	Total	66 271	20 276	86 547

* *In situ* reserves include all coal irrespective of the thickness of individual layers
† 'Opencastable' is the area where the Upper Ecca coal can be mined at stripping ratio of at most 0,98 bank cubic metres (BCM) per ton of raw coal
‡ 'State area' is the area where the State has reserved mineral rights
§ 'Other' refers to areas where mineral rights are held by the private sector

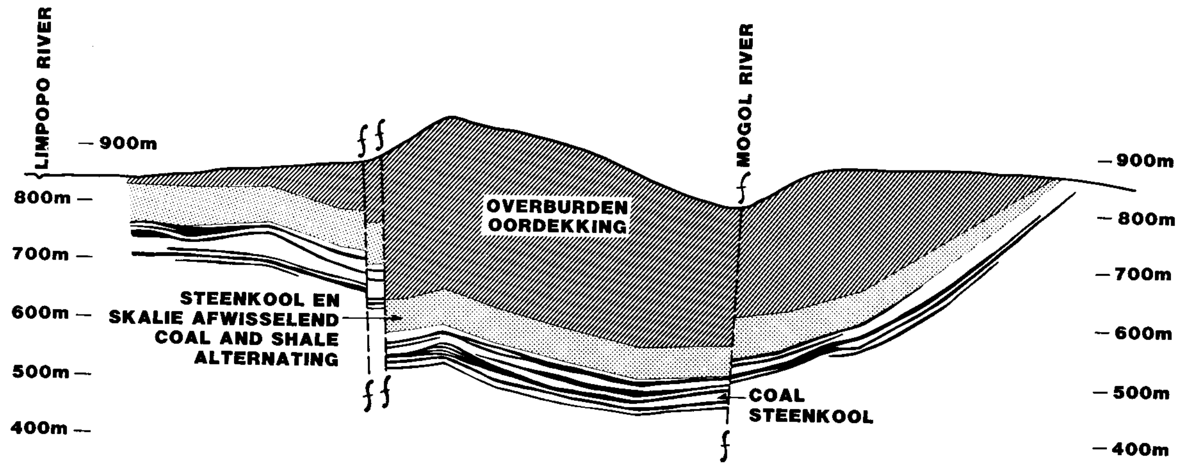

Fig. 2—Section through the Waterberg Coalfield

Underground Mineable Reserves

Underground mineable reserves are located between 100 and 450 m below the surface. A schematic profile (Fig. 2) indicates the Upper Ecca coal succession (about 60 m thick) consisting of alternating layers of coal and mudstone. The thickness of the individual coal layers varies from a few centimetres to 1 m or more in exceptional cases.

De Jager[11] (p. 6) considers the coal in the seven zones of the Upper Ecca Group as follows:

> The run-of-mine product from the seven composite seams of the upper coal zone will have to pass through an industrial beneficiation process for an acceptable (enriched) end product, even for steam-raising purposes. Thus, in areas where underground mining will be necessary, . . . a minimum and maximum mining height of 2,0 and 3,5 m respectively and a minimum clean-coal thickness of around one metre were taken for reserve determination.

If De Jager's approach for underground reserves at depths of 100 to 450 m is applied to a typical borehole profile, seven possibly recoverable units can be considered (Fig. 3). However, this approach has to be modified to provide for mining heights greater than 3,5 m, as well as for the separating layers. The right-hand side of the profile then shows, according to an alternative approach, seven recoverable units (1 to 7), while the left-hand side shows 2 m units according to De Jager's approach.

According to De Jager, there is a 2 m mineable unit with an *in situ* ash content of 40,3 per cent at the base of zone 10, whereas the alternative approach makes possible a mining height of 6,1 m with an *in situ* ash content of 36,3 per cent. According to the *in situ* ash values of the different recoverable units, it is clear that unit 3 at the bottom of zone 9 is the only one that can be mined without beneficiating the coal. According to the present view, unit 3 will therefore be the only unit that can be recovered economically—thickness 2,4 m, *in situ* ash content 25,9 per cent (Fig. 3). This approach limits the exploitation of the bright-coal reserves in the Upper Ecca.

By a similar approach, two possible mining horizons can be distinguished in the Middle Ecca:

Zone 3 with a mining height of about 3 m
Zone 2 with a mining height of about 4 m.

The two seams are separated by a sandstone layer of 6 m. These two zones represent dull coal for which beneficia-

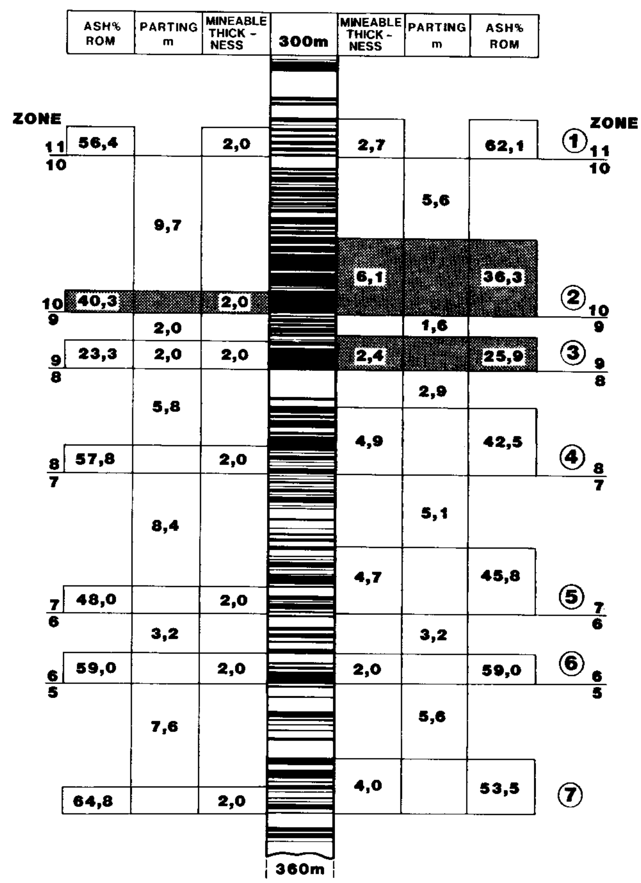

Fig. 3—Upper Ecca zones 5 to 11 in the Waterberg Coalfield (ROM = run-of-mine)

tion, depending on the application, may not be required.

De Jager[11] (p. 7) summarized the extractability of coal in the Waterberg Coalfield as follows:

> It is not yet possible to arrive at a sophisticated estimate of a recoverable reserve for the Waterberg coalfield [*sic*], since a number of presently still unquantifiable factors have to be considered such as the mineability on a large scale by underground and open-cast means. By rule of thumb, a figure of 18 000 million tons has been accepted as recoverable, namely about 36% of the *in situ* mineable reserve.

If economic considerations dictate an approach that excludes beneficiation, then only unit 3 in the Upper Ecca (Fig. 3) can be mined (at a mining height of 2,4 m). If this is accepted, the recoverable reserves can be calculated as follows:

Total area	79 000 ha
Mining height	2,41 m
Relative density	1,60
Raw coal *in situ*	3046 Mt
Assumed geological losses	10%
Recovery by high-recovery mining	80%
Recoverable reserves	2193 Mt with 25,91% ash.

This approach greatly limits the recovery of deep coal in the Upper Ecca. Only 2193 Mt of a potential 42 217 Mt of coal *in situ* is then utilized. This approach gives rise to a utilization of only 5,2 per cent of the deep bright-coal reserves in the Upper Ecca. The same approach is used for estimates A and B in Table XIII.

According to the same approach for the two mining units in the Middle Ecca, the recoverable reserves are 6515 Mt.

Opencastable Coal Reserves

A dual approach can be followed for the calculation of the opencastable reserves.

Assessment A

In this case the mining of the opencastable bright-coal zones of the Upper Ecca, excluding those zones in the Grootegeluk area (1134 Mt), is not regarded as an economic proposition, i.e. on the assumption that only a low-ash product is required or can be marketed. It is further assumed that the coal in zones 2 and 3 of the Middle Ecca in both the shallow and deep-lying areas will be mined by means of maximum-extraction underground mining. However, the underground mining of zones 2 and 3 in the shallow-lying areas creates the danger of spontaneous combustion in the bright-coal zones owing to possible cracks to the surface that could act as ducts for oxygen.

Assessment B

The opencastable bright-coal zones are regarded as being economically mineable, and the reserves will therefore be exploited to the maximum. The full exploitation of the dull-coal zones is therefore also made possible.

The result of both approaches is summarized in Table XVI and reflects a meaningful difference in recoverable reserves in the two cases.

The Waterberg Coal Reserves That Are Economically Exploitable

The reserve figure of 17 260 Mt of mineable coal (assessment A) is 21 088 Mt less than the 38 708 Mt of assessment B. This difference is due to the assumption that, in one instance, opencast reserves are exploitable and in the other they are not. An evaluation of the properties of the raw Upper Ecca coal succession (Table XIV) and the information regarding the mineability of opencastable coal in the Upper Ecca (Table XV) explain the uncertainty about the economy of opencasting this coal.

The Upper Ecca opencastable coal will have to be mined by the conventional truck-and-shovel method. This method is relatively expensive and, in view of all the circumstances, it must be concluded that the production cost of opencastable coal from the Upper Ecca will be high.

A review of the exploitable reserves (Table XIII) leads to the following inferences.

- It is essential that opencasting as a mining method be applied to its maximum in this coalfield to avoid the

TABLE XIII

COMPARISON BETWEEN *IN SITU* AND RECOVERABLE RESERVES IN THE WATERBERG COALFIELD

(Iscor estimate)

	Bright coal		Dull coal		Total	
	A*	B†	A*	B*	A*	B†
Opencastable						
In situ	24 054	24 054	10 224	10 224	34 278	34 278
Recoverable	1 134‡	20 000§	7 418∮	10 000∮∮	8 552	30 000
Deep coal						
In situ	42 217	42 217	10 052	10 052	52 269	52 269
Recoverable	2 193**	2 193	6 515††	6 515	8 708	8 708
Total						
In situ	66 271	66 271	20 276	20 276	86 547	86 547
Recoverable	3 327	22 193	13 933	16 515	17 260	38 708
Percentage recovery of reserves	–	–	–	–	19,94	44,72

* *In situ* includes all the coal occurring in the coal succession
† *Recoverable* provides for geological and mining losses
‡ Case A indicates only the recoverable bright-coal reserves in the Grootegeluk mining area because it is assumed that the remainder of the opencastable bright-coal zones cannot be exploited economically
§ In case B, it is assumed that the bright-coal zones (opencastable) are mined and beneficiated because this is regarded as economically feasible
∮ Opencastable reserves of the Grootegeluk mining area plus underground reserves of zones 2 and 3
∮∮ Exploitation of the bright-coal zones enables better utilization to be made of these zones by opencast mining methods
** Underground recoverable reserves of only one horizon, namely the base of zone 9, where the ash value of the raw coal is 25,91 per cent
†† Underground recoverable reserves of zones 2 and 3

TABLE XIV
PROPERTIES OF UPPER ECCA COAL SUCCESSION

Relative density of raw coal	Ash content of raw coal	Yield at 10,4% ash	Yield at 35% ash	Ash content of plant waste	Tendency to spontaneous combustion	
					Raw coal	Plant waste
1,8	55,0%	11,0%	54,8%	80,0%	Very high	High

TABLE XV
MINEABILITY OF OPENCASTABLE UPPER ECCA COAL SUCCESSION

Approximate average thickness of overburden in opencastable portion m	Average stripping ratio BCM per ton of raw coal	Stripping ratio BCM per ton of beneficiated product at 35% ash
50	0,54	1,73

sterilization of 21 448 Mt of coal (38 708 minus 17 260 Mt). The only meaningful way to achieve this is by the establishment of multi-product mines such as the Grootegeluk Mine, where coal at 10,4 per cent ash is produced for coking purposes, and a middlings fraction at 35 per cent ash becomes available as thermal coal for Escom.

- If the opencast potential is not utilized, zones 2 and 3 make the major contribution to mineable reserves, viz 13 933 Mt out of a total of 17 260 Mt. The ash values of the raw coal in zones 2 and 3 are 25 and 23 per cent respectively. If a low-ash coal is required, beneficiation will be necessary, with a resultant increase in production cost. *Consideration of the transport costs of approximately R55 per ton to Richards Bay leads to the conclusion that coal exports from the Waterberg will probably never be economically feasible. When the South African reserves are therefore considered with export planning in mind, the reserves in the Waterberg field must be excluded.*
- The bright coal in the deeper areas will probably not be extractable, and almost half the *in situ* reserves of the Waterberg Coalfield may remain inaccessible (42 217 minus 2193 Mt of 86 547 Mt).
- It is therefore absolutely imperative that the economically exploitable reserves for the Waterberg Coalfield be determined with due consideration of the following:
  - a practical mining strategy
  - the different types and qualities that can be produced
  - realistic production costs for the different types and qualities.

The outcome of this investigation will supply the information required to place the coal reserves of the Republic of South Africa into perspective.

Conclusions Based on the Waterberg Coalfield Reserves

The latest figures (*in situ* mineable and recoverable) show a meaningful increase of both the *in situ* mineable reserves and the extractable reserves (assessment B of Table XVI) in comparison with De Jager's figures.

The most conservative estimate of reserves for the Waterberg Coalfield arrives at 17 260 Mt of exploitable coal against De Jager's figure of 18 000 Mt, which he qualified as follows: 'By rule of thumb, a figure of 18 000 million tons has been accepted as recoverable'. According to another approach, the figure is 38 708 Mt, i.e. 21 448 Mt more than De Jager's figure. The actual figure is probably somewhere in between, and it must be concluded that the figure of 18 000 Mt quoted by De Jager is *probably too conservative* but, in the long run, economics will dictate the final figure (Table XVI).

The Exploitability Potential of the Soutpansberg Coalfield

In a search for high-rank straight coking coal, Iscor

TABLE XVI
COAL RESERVES IN THE WATERBERG COALFIELD BASED ON THE LATEST FIGURES, COMPARED WITH DE JAGER'S ESTIMATE

Field	*In situ* mineable		Extractable				Difference	
				Alberts			Extractable	
	De Jager	Alberts	De Jager	Assessment A	Assessment B	*In situ* mineable	Assessment A	Assessment B
Waterberg: Upper	23 303*	56 461†	–	3 327	22 193	+33 158	–	–
Lower	26 620	20 276	–	13 933	16 515	–6 344	–	–
Total	49 923	76 737	18 000	17 260	38 708	+26 814	–740	+20 708

* The method used by De Jager to calculate this figure is not evident from his report

† Alberts (the present author) calculated the *in situ* mineable reserves by assuming the thickness of the Upper Ecca coal sequence to average 60 m, and assuming that the maximum mining height is 6 m and the distance between the floor of the working place and the roof of the next lower stope is 2 m. In a sequence of 60 m, 46 m can therefore be mined by underground methods (76,6%). (This formula is merely intended to illustrate an extreme approach.)

investigated coal deposits in the Waterpoort area during the period 1959–1963. Since 1973, this investigation has been extended eastwards into the Republic of Venda, where Iscor is currently conducting trial mining at the Tshikondeni Mine. In total, more than 2000 boreholes have been sunk in the Soutpansberg Coalfield, and several bulk samples have been taken from a box-cut and from several exploration shafts for large-scale beneficiation and metallurgical tests.

The nature of the coal deposits gradually changes from a multi-seam coal–mudstone association 40 m thick in the Waterpoort area to two individual seams in the east: the upper seam 3 m thick, and the lower seam some 100 m deeper and 2 m thick. The coal seams dip consistently to the north (5 to 20 degrees) and are intensely disturbed by faults and dolerite intrusions.

Dull coal occurs locally at the base of the multi-seam coal–mudtone association in the Waterpoort area, and the upper part of the lower seam in the Tshikondeni area also consists of dull coal. Otherwise, Soutpansberg coal is predominantly bright and high in vitrinite. The rank gradually increases from west to east: the content of volatile matter at Waterpoort is 35 per cent as against 25 per cent at Tshikondeni. The reserve figures for Iscor's interests in the Soutpansberg are given in Table XVII.

TABLE XVII

IN SITU MINEABLE COAL RESERVES IN ISCOR INTERESTS IN THE SOUTPANSBERG

Area	*In situ* mineable reserves Mt	Extractable reserves Mt
Waterpoort	120	50
Block C Annex	30	15
Block C	149	30
Block C North	89	30
Mopane	93	42
Block D	24	15
Tshikondeni (Block E)	91	46
Total	596	228

Iscor considers the E-block (Tshikondeni area in the Republic of Venda) as the only area north of the Soutpansberg that can be exploited economically at present, and then only because of the excellent quality of the coking coal. The other areas will probably never be developed for applications in which low-cost coal is a prerequisite, such as for power generation.

Exploration work has proved significant reserves in certain areas. Recent pre-feasibility studies in the most promising areas within the Republic of South Africa indicate high production costs because of difficult mining conditions and a relatively low yield. It can therefore be concluded that the economic exploitation of this field as a whole is questionable.

De Jager[11] (p. 7) reported, for the Soutpansberg excluding the Republic of Venda, 1450 Mt of *in situ* mineable and 725 Mt of recoverable coal (Table VIII). Only the Tshikondeni reserve appears to be economically exploitable and, at the most, 20 million sales tons can be expected from the 46 Mt of extractable reserve. Furthermore, Tshikondeni is situated in the Republic of Venda and therefore the economically exploitable reserves of the Soutpansberg Coalfield must be decreased significantly. This conclusion changes the reserve figures (for mining to a depth of 300 m) for the Soutpansberg as shown in Table XVII.

The Economically Recoverable Coal Reserves in Natal

The *in situ* mineable coal reserves in Natal according to De Jager[11] are shown in Table XVIII.

TABLE XVIII

IN SITU MINEABLE BITUMINOUS COAL IN THE UTRECHT, KLIP RIVER, AND VRYHEID COALFIELDS

Area	De Jager Mt	Alberts
Utrecht	749	Limited
Klip River	705	Limited
Vryheid	86	Limited
Total	1 540	100?

Mining activities in this area over the past seventy-five years have supplied much information on these fields. The following is an example of the exploitability potential.

Iscor owns a coal deposit on the farm Klipplaatdrift, in the Utrecht district, and therefore has first-hand information on this area. Large dolerite intrusions are common in this coal deposit. Economic mining of the coal at Klipplaatdrift is regarded as improbable owing to the depth of the coal (up to 600 m), the yield when beneficiated, and the quality, which by modern coking-coal standards barely meets blend coking-coal requirements.

The Klipplaatdrift deposit as described is considered typical for most of the Utrecht area, and further coal mining in this area will therefore take place only where reserves have a better potential or are located in the vicinity of existing mines where an infrastructure exists.

The same arguments apply to the Klip River and Vryheid fields. The high production cost of coal in these areas owing to the depth of the coal and the thinness of the coal seams makes economical mining improbable, and the reserve figure of 1540 Mt must be decreased by approximately 1400 Mt as shown in Table XVIII.

The general scarcity of coking coal and the high cost of straight coking coal from these fields have already resulted in Iscor's decision to construct a Corex plant at Pretoria. In the Corex process, high-grade iron ore is reduced by a relatively low-grade bituminous coal, which is more readily available and considerably cheaper than coking coal. The process uses two reactors one on top of the other, i.e. a smelting furnace below and a prereduction furnace above. The waste gases, which are rich in carbon monoxide, are fed from the smelting furnace to the reduction furnace, in which ore is heated and partly reduced before being hot-charged into the smelter. High-velocity oxygen is injected into the smelter, which also contains a fluidized bed of carbon derived from the coal, and the partly reduced ore is further reduced and smelted into liquid iron in this fluidized bed. The liquid iron and slag are tapped from the furnace in the same way as from a blast furnace. Fluxes (lime and dolomite) are charged together with the coal or ore. The control of this process is more flexible than that of blast furnaces, since the slag volume and slag composition can be continuously adjusted by the blowing in of additional fluxes.

It is expected that the production cost of the iron will be appreciably lower than that of iron produced by the conventional route involving a blast furnace and coke ovens, mainly owing to the use of cheap bituminous coal instead of coking coal. In effect, the Corex process eliminates Soutpansberg coal as a reserve because it will be too expensive for applications other than the production of coke.

A Comparison between De Jager's and Alberts's Reserve Estimates

The recoverable reserves determined in accordance with a different approach—that taken by the present author—are shown in Table XIX.

TABLE XIX
UPDATED COAL RESERVES (Mt) ACCORDING TO ISCOR INFORMATION BASED ON SPECIFIC ASSUMPTIONS

	Difference in mineable reserves	
	Alberts's assumption A *vis-a-vis* De Jager	Alberts's assumption B *vis-a-vis* De Jager
*Areas in Table VIII where no changes were made	37 763	37 763
Utrecht, Klip River, Vryheid	−1 003	−1 003
Soutpansberg	−725	−725
Waterberg Upper		
Lower		
Total	−740	+20 708
Grand total	−2 468	+18 980

* For purposes of this table, De Jager's data were used for the areas in which Iscor is not directly involved

The main conclusions from this revision of reserves are as follows.

- The exploitation of the remaining *in situ* mineable reserves in the Klip River, Utrecht, and Vryheid Coalfields is highly unlikely.
- Exploitation of only part of the Soutpansberg Coalfield will be feasible and for special use only. (The area that can be mined economically is situated outside the borders of the Republic of South Africa.)
- The Waterberg Coalfield has the greatest *in situ* mineable reserves in South Africa. The mining of this field greatly depends on whether it will be an economic proposition.
- The updating of the economic coal reserves in the Republic of South Africa on a regular basis is a necessity if they are to stay abreast of the economy as a whole.
- According to the approach followed here, 2468 Mt of reserves in three areas are no longer economically exploitable, and *the question arises as to what percentage of the 37 763 Mt of mineable reserves for all the other coalfields in South Africa are economically mineable under present-day conditions (Table XIX).*

The Geological Survey is busy updating the coal reserves, and the following questions come to mind.

What assumptions will be used?
Into what categories will the coal be divided?
Will investigations be conducted independently by the Geological Survey?
Will *ad hoc* assistance be obtained from the coal-mining industry?
Would an informal panel from the coal-mining industry not provide the answer?
Should a formal panel be used, and to whom would the panel be accountable?
Would another commission not be better?

The Status of Coal Exports and a Prognosis of the Future

The last two official surveys of coal reserves were intended to provide the necessary information for use in the planning of exports. It is therefore appropriate to review the situation in the coal-export industry with due cognisance of the forecast made at the time when the export scheme was conceived and also to take a look into the future.

R.E. Burnton made the following remark in his paper mentioned earlier and entitled 'Coal as a Source of Energy':

> Without discounting the future it is to be accepted that our country must somehow now earn the foreign currency it needs to pay for the imported capital goods which will generate its future energy and, indeed for the increasing oil import bill. Against this background, earnings of approximately R1 000 million per annum in the 1980's fall into perspective. There is currently no additional prospect of any other export industry able to earn foreign exchange on this scale.

The increase in extractable reserves as reported by the Geological Survey gave rise to the following reaction (Coal; A Survey, Supplement to *Financial Mail,* 14th August, 1981):

> The recent doubling of the official estimates of SA's extractable reserves to 51 000 Mt left little doubt in the minds of leading producers that the department would recommend another phase of exports.
>
> It also raised the expectations of companies that have been champing at the bit to get into lucrative foreign markets.

In the introductory article of the same publication, the following remark is made:

> Only eight years after a fairy godmother came calling in Arab garb, the cinderella of SA industry has grown up and gone to the ball.
>
> The story of coal's coming of age certainly does have a fairytale ring about it.
>
> Who would have thought, as recently as 1971, that sane and sober coal managers would now be talking of a national output of 240 Mt by 1990? And exports of 60 Mt–70 Mt, or that more than R20 billion in today's money would have to be invested in coal and coal-related developments in the next decade?
>
> The talk is breathtaking, but the good thing about it is that it's no fairytale. No clock is going to turn this cinderella's coach into a pumpkin. To the contrary, time may tell that these prognostications were conservative.

So already coal has sped ahead of diamonds (1980: R553 m) in foreign earnings. The success brings closer the day when this carboniferous relic of 250 M years ago will eventually be more valuable to SA than its gold.

The second Coal Age has had a glowing beginning – and there's every indication the glow will get brighter and brighter.

'The only growth area we can forecast for the next five years is coal', says Dr Dirk Neethling, Chief Director (Energy) in the Department of Mineral and Energy Affairs. 'It's a super-growth sector'.

According to the Financial Times International Coal Report (ICR) for 1986, peak coal prices were realised in mid 1981—a retrospectively incredible US \$65/t for Australian coal delivered to Europe, while South African coal to the same destinations attained a delivered price of around \$59 in early 1982.

By the end of 1986, however, delivered prices were down to a range of \$29–\$35 for all major destinations, with South African exports at the bottom end of this range. And the sharp fall in the dollar has meant that energy prices have fallen proportionately more in terms of other major currencies.

The projections, coupled by most bodies to the prices reached on world markets, led everyone in South Africa who had coal at his disposal to conclude that participation in this attractive investment market was essential and that it should be entered into as quickly as possible. It was even argued that export opportunities had been earned by previous 'subsidizing' of the South African price.

The actual course of events and the present prognosis look rather different from what had been projected (Fig. 4).

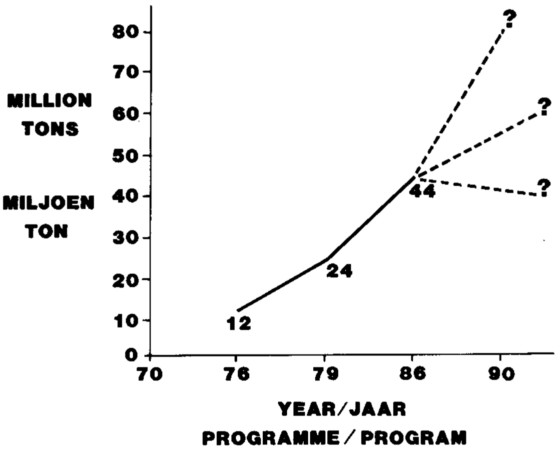

Fig. 4—Coal-export capacity from Richards Bay

An extract from an article in the *Financial Mail* of 26th June, 1987, entitled 'The Seven Lean Years' sums up the situation best:

That nice warm glow conferred by coal exports to SA's balance of payments is quickly dying down. We've had seven fat years; now prospects are wintry for the foreseeable future. The squeeze on export tonnage and profits will not be easily or quickly reversed. The years ahead will be tough for exporters, whose contribution to the Balance of Payments (BOP) surplus will be minimal. And the constraint, unfortunately, will ripple throughout the economy.

Last year, SA exported 45,4 Mt of coal of all grades and through all ports.

Reliable sources suggest that coal exports for the first quarter of 1987 were 9,8 Mt on preliminary estimates—compared with 11,4 Mt for the first quarter of 1986. If the first quarter's figures are annualised (a shaky statistical exercise), then exports for the whole of the current year could turn out somewhere in the vicinity of 39 Mt to 40 Mt.

Turning to the international picture, we can now see that world seaborne coal trade peaked in 1985 at around 275 Mt. Last year saw a slight decline, and the current year could see a further small drop. The reason is simple.

Not for the first time, and surely not for the last, the long lead times required to develop mining capacity interacted with the demand side to ensure that a phase of over-production would follow the seven fat years.

One of the main causes of the above-mentioned problems is the fact that long-term predictions may be influenced by a whole series of variables. The entire forecast process is risky, especially if an attempt is made to forecast a world demand that is subject to political and economic developments in different parts of the world. An aspect that is difficult to define and often neglected in planning is the influence of a country's development status on its need for various goods and services.

The history of the iron-ore market best bears witness to the influence of over-optimism, uncoordinated planning, the economic situation in the world, and consideration of only some of the factors that will influence the demand for iron and steel.

The prognosis for the Japanese demand for iron and steel was published in an article entitled 'Japan and the Prognosticators' in *The Magazine of Metals Producing* of September 1970 (Fig. 5). The actual demand to date is shown in the diagram. The normal human over-optimism is clearly revealed in the results. Unfortunately, new mines were developed to deal with the anticipated demand, with the result that mines now ready for production cannot be fully utilized.

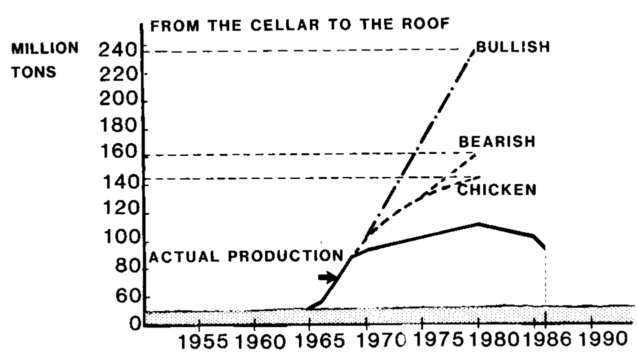

Fig. 5—Japanese production of raw steel. (Source: ***The Magazine of Metals Producing,*** **Sep. 1970)**

Such development resulted in the world's installed production capacity of iron ore (65 per cent iron content) exceeding the demand by 42,5 per cent or 345 Mt iron ore with an iron content of 65 per cent (Fig. 6).

The situation has had a catastrophic effect on prices, mainly because, in the resulting price war, iron-ore producers are doing their utmost to maintain volumes. This is reflected in the ore prices of the last five years (Table XX).

Japanese and South African Views of Contracts

South African entrepreneurs envisaging trade with Eastern countries must be fully informed regarding the Eastern view of contracts. Significant differences in the interpretation of contract obligations prevail between

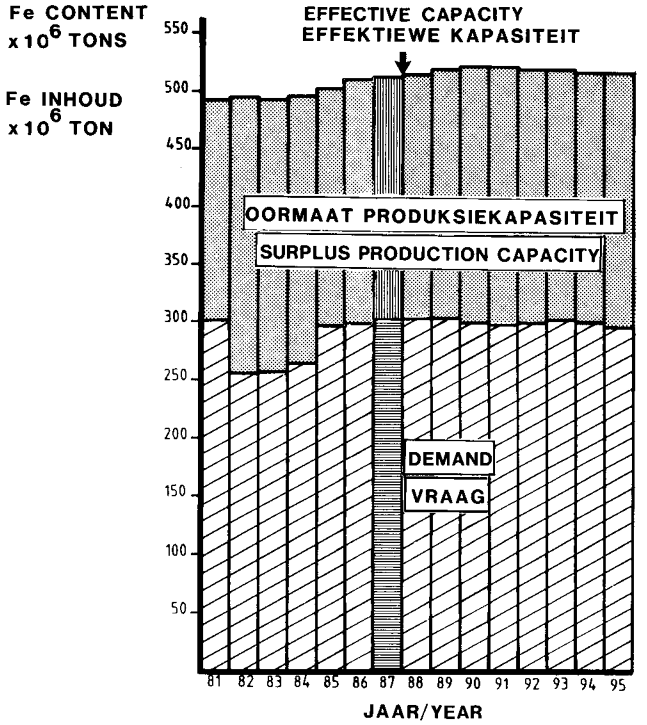

Fig. 6—Estimated production capacity and demand for iron ore in the Free World

TABLE XX
PRICE TREND FOR IRON ORE: JAPAN AND EUROPE

Year	Price trend: Japan %	Price trend: Europe %
1983	−12,0	−12,0
1984	−10,0	−10,0
1985	+1,0	+1,0
1986	−4,5	−1,5
1987	−5,5	−8,0

Eastern and Western businessmen. This difference complicates Eastern and Western business relationships. The Eastern view of contracts has been spelt out by a senior member of the Japanese steel industry in a paper entitled 'Contract Renewal—Basic Thoughts'. The Western view of a contract is that it is a rigid commitment, the terms and conditions of which must be adhered to by the contracting parties. On the other hand, the Eastern view is that a contract is a basis for further negotiations when the need arises. The contract merely regulates the basis or the broad principles of the relationship between the contracting parties.

Experience shows that, in spite of existing contracts that lay down tonnages to be supplied and the buyers' requirements, buyers of raw materials are still entering into contracts with new and additional suppliers, which result in further oversupply and an increase in the chaos currently experienced in the iron-ore market. The net result will certainly be subsidies by governments and liquidations of supply companies.

Coal exporters and potential coal exporters must take heed of the above when planning for export.

World Coal Position

Coal exporters are now entering a phase in which the iron-ore industry has found itself since 1982. Oversupply is the order of the day in this industry. A quotation from 'The Seven Lean Years', an article in the *Financial Mail* of 26th June, 1987, confirms this by indicating that, despite the present status of oversupply, further extensions are being planned:

> Chinese coal exports could rise from nearly 10 Mt in 1986 to 30 Mt for 1990 and 35 Mt the following year, while Colombia could have 22 Mt available by 1995.
>
> The most important importer by far was Japan at 89,4 Mt, followed by South Korea and Italy, each at around 20 Mt, with a number of other importers coming in at well under 20 Mt.
>
> Reliable sources suggest that the current price structure is hurting many exporters—SA aside—rather badly. Some Australian mines are operating at a loss, while the developing El Cerrejon project in Colombia (a partnership between government and Exxon) could not—selling at current prices—even service the capital committed to the mine and to its dedicated rail line and port.
>
> That volume exports have held up as well as they have in the face of a setback of this magnitude is partly a tribute to marketing diligence on the part of the local industry, and partly a reflection of a *willingness to cut prices* rather *than volumes.*
>
> There are some important implications for public policy because of the prospect of a significant period of low export earnings from coal. The most obvious is that any thought of a Phase IV expansion at Richards Bay is dead for the foreseeable future.

The world's coal reserves and the coal-production levels in the major producing countries, together with the effect of the considerable and essential demand for foreign exchange on the future supply of coal (and other raw materials), must be thoroughly considered in the planning of future supplies of coal or other raw materials.

From the 'Survey of energy resources (1986)' conducted by the World Energy Conference[13], the ten countries leading with proven *in situ* reserves of bituminous and sub-bituminous coal are ranked as shown in Table XXI.

TABLE XXI
WORLD RESERVES AND RESOURCES OF BITUMINOUS AND SUB-BITUMINOUS COAL

Country	Proven *in situ* Mt	Estimated *in situ* Mt	Total *in situ* Mt	Proven as % of total
China (1984)	610 600	1 700 000	2 310 600	26,42
USA (1984)	402 006	734 307	1 136 313	54,75
USSR (1984)	187 800	8 248 900	4 436 700	4,42
Rep. of SA (1984)	115 530	17 100	132 630	87,11
Poland (1983)	63 000	100 500	163 500	38,53
Australia (1984)	51 526	607 400	658 926	7,82
Great Britain*	45 000	185 400	230 400	19,53
Germany (Fed. Rep.) (1984)	44 000	186 300	230 300	19,11
India (1981)	26 331	85 547	111 878	23,54
Mongolia (1984)	12 000	–	–	–

* Estimated from another source

Note: The coalfields of Southern Africa, Australia, and India are part of the original Gondwanaland, and a degree of similarity of coal development in these coalfields can be expected. Yet, for the Republic of South Africa, 87,11% of the total reserves are considered proven according to De Jager's figures (1982), as against 23,54% for India and 7,82% for Australia. Does this merely reflect the advanced state of coal exploration in the Republic of South Africa or does it imply that different countries have different concepts of 'proven reserves'?

According to the 'Survey of energy resources (1986)'[13], coal production by the ten leading countries for 1984 was as indicated in Table XXII (Great Britain 1983). The production figures for 1986 as published in *BP Statistical Review of World Energy* of June 1987 are also given in Table XXII.

TABLE XXII
WORLD COAL PRODUCTION

Country	Year, Mt 1984	1986
China	759	825
USA	755,4	750
USSR	590	591
Poland	191,5	192
Republic of SA	162	182
India	144	155
Great Britain	116,5 (1983)	108
Australia	104	152
Germany (Fed. Rep.)	79,4	87
Canada	47,5	30

This information on reserves and production clearly illustrates the ability of countries to increase production should circumstances require it. Table XXII shows which countries are expanding their capacity. The most important are China, South Africa, India, and Australia. An article in *Metal Bulletin* of 16th July, 1987, entitled 'China Seeks Bigger Stake in Coal Market' is significant and illustrates that coal is following the same direction as iron ore because, even at this moment, in spite of an oversupply, increased production is being planned.

While acknowledging China's potential as a major coal producer and exporter, a report released last month by Japan's Institute of Energy Economics questions whether China will actually be able to deliver on its promises. The report was the result of an 11 month joint study, conducted by the IEE and China's Energy Research Institute.

Thanks to what is described as a range of 'positive incentive measures' taken by China, the researchers estimate that Chinese coal exports are likely to rise by 20% a year over the next few years, slowing to around 10% annually during the 1990's. These measures include the expansion of port and railway systems, improvement of mine operating efficiency and coal quality, and the removal in January this year of the government's 20% export duty.

The report estimates that China exported 9,9 M tons of coal last year, of which 6,7 M tons was steaming coal and 3,2 M tons coking coal. One third of the latter was shipped to Japan. The Chinese hope to export about 16 M tonnes of coal worldwide this year, although Japanese officials suggest between 10 M and 11 M tons might be closer to the actual outcome.

China intends to export 30 M tons by 1990. The report however, quotes Chinese officials who concede that numerous obstacles exist. The researchers concluded that 20 M tpy by 1990 might be more realistic. If the same proportion of steaming and metallurgical coal is maintained, around one third of this could be coking coal.

With its massive export capacity being maintained or an ambitious target to boost its export capacity being mapped out, the report warned, 'China could have a great impact on coal supply-demand and prices on international markets only if it drives positive export policies forward.'

The prognosis therefore is that the world's coal-production capacity is exceeding demand and will in the near future exceed it even further, with all the disadvantages that this entails. This situation results in valuable South African raw-material reserves being sold and exported at prices at which, under normal circumstances, nobody would be prepared to sell. However, the need to survive leaves no other choice.

The major exposure, due to world market uncertainty, of entrepreneurs whose income depends completely on exports, the high inflation rate at home, the rate of exchange, and the political manipulation of business very clearly show that Mr Steve Ellis was partly right when he put Gencor's approach in 'Coal; A Survey' (supplement to the *Financial Mail*, 14th August, 1981):

Gencor opts for double duty

The head of Gencor's coal division says he can think of no better way of financing greater production for the inland market than by expanding an Escom mine for a secondary role in higher-income exports.

Foreign sales have, in effect, generated their own resources, Ellis notes. This has allowed the country's major coal producers to go for more multi-product mines and to employ more efficient extraction equipment and methods—making possible deeper strip mining, for instance.

Mr Ellis's approach is that exposure should be distributed. Until last year, his conclusion that the revenue from foreign contracts would supplement the inland advantage was correct. However, the prognosis now is that reliable inland markets with buyers who honour their contracts will in future be the foundation on which exports must be planned. The future will show that the best investment will be one with a contract for local deliveries that will enable the entrepreneur to service his debt, and be able to produce 25 to 30 per cent more for the foreign market, or to supply products to the foreign market. In this way, the entrepreneur can insure himself against the uncertainties of the foreign market.

The Influence of the Exchange Rate and Inflation on Exports

The future of raw-materials exports is also very seriously threatened by the high local rate of inflation and the uncertain pattern of the rand–dollar rate of exchange (Table XXIII).

TABLE XXIII
THE RAND-DOLLAR RATE OF EXCHANGE, 1979 TO 1987, AND THE ANNUAL INFLATION RATE

Rate of exchange*		Annual average rate of inflation per year†
Year	%	%
1979	+ 3,2	–
1980	+ 7,5	–
1981	– 12,7	15,2
1982	– 23,7	14,7
1983	– 2,5	12,3
1984	– 32,5	11,7
1985	– 51,0	16,2
1986	– 2,5	18,6
1987	+ 10,8‡	–

* Average of year compared with the average of the previous year (Reserve Bank)
† Consumers' Price Index—average per year (Central Statistical Service)
‡ Average of first 6 months of 1987 compared with the average of the 12 months of 1986

A hypothetical example of a project based on the following assumptions can be used to illustrate the effect of inflation and exchange rate (Table XXIV).

TABLE XXIV

ASSUMPTIONS FOR THE PROJECT

Conditions:

Capital expenditure	R5 800 000
Life	7 years
Residual value	None
Income	R13 800 000 ($5 000 000 at an exchange rate of R1 = $0,36)
Expenditure	R7 000 000
Price basis	January 1985

Excalation and exchange rate:

Year	1985	1986	1987	1988	1989	1990	1991
Escalation, %:							
Local (domestic)	17	20	17	16	15	15	14
Overseas	4	4	6	6	6	6	6
Exchange rate, R1 =	$0,36	$0,44	$0,50	$0,46	$0,42	$0,39	$0,39

Note: For 1987 to 1991 the planned rate of exchange is based on the purchase power parity theory

If the effect of escalation and the rate of exchange are disregarded, the cash-flow advantage as indicated in Fig. 7 is R6 800 000 per annum (i.e. R13 800 000 income minus R8 200 000 expenditure). For a capital expenditure of R5 800 000, the internal rate of return is 117 per cent over a 7-year evaluation period.

The result of the escalation of income and expenditure as taken into account at the 1985 exchange rate is shown graphically in Fig. 7. As a result of the large difference between the foreign and the local rates of inflation, the lines converge. The internal rate of return drops to 89 per cent, and by 1991 expenditure outstrips income, resulting in a serious situation of loss.

When the exchange rate is taken into account (i.e. the real situation), the income in rands would be equal to the expenditure in rands within 2 years—once again, a situation of loss that would deteriorate if the rand did not sink as low as shown in the example.

The hypothetical example (Fig. 7) illustrates the statement made earlier that, in view of the high local inflation rate, calculations in respect of any large-scale project should be based on an assured local demand. Exports can then be justified only by the extremely marginal costs and preferably should not determine or influence the viability of the project.

A major contributor to the high South African inflation rate is the goose laying the golden eggs, namely the gold-mining industry. This industry's progressive approach with regard to wages and salaries, which is made possible by the unique situation of South Africa supplying nearly 50 per cent of the world's gold, and which also flows from the 'ability to pay', results in the other mining operations and industries in the country, which make use of the same labour pool, having to pay the same wages and salaries in order to retain their labour. However, they are competing in very competitive world markets against competitors with a better productivity record (higher productivity makes higher wages and salaries possible) and with a more disciplined wages and salary policy. If the South African raw-materials export industry is to survive, this situation will have to be rectified.

Conclusions

The following conclusions can be drawn from the foregoing discussions.

(1) The difference in the quality and geographical location of coal occurrences, with many variables in-

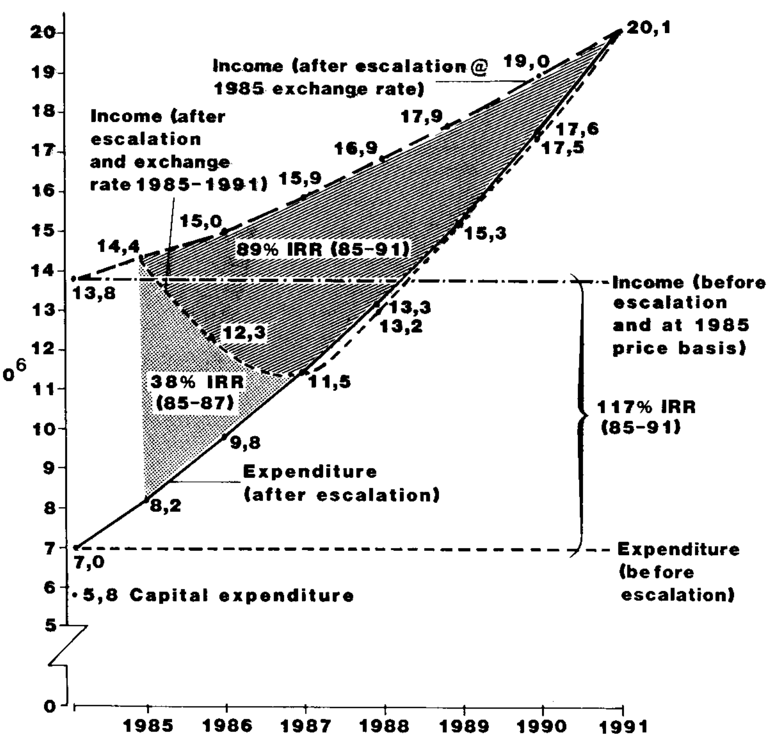

Fig. 7—Various evaluations (IRR) of an export project

fluencing the cost of extraction, the uncertainty surrounding the reliability of past reserve estimates due to the lack of published assumptions and of information upon which the calculations were based, and the need for reliable information for the planning of South Africa's energy reserves, make the proper updating of coal-reserve figures according to a standard approach (e.g. that followed by Petrick and his team) a necessity.

(2) The members of the project team to be appointed for such updating must be representative of all involved in the coal industry, that is the State and the private sector, and such a team must be appointed officially by the State President.

(3) It is essential that, after having agreed upon the assumptions to be used in determining the reserve figures, this team should communicate these assumptions to the entire coal industry for understanding and acceptance before carrying on with the investigation.

(4) Although a start has already been made with a new updating of the coal reserves, it is probably not too late to modify the approach to be used in this investigation; otherwise, it will once again provide the subject matter for a presidential address.

(5) The history of raw-materials exports, with specific reference to the export pattern of iron ore and manganese ore, and the prognosis for coal exports, point to the necessity that past events should be taken into consideration.

(6) The uncertainty on the world market, the high domestic internal rate of inflation, the unpredictability of the monetary rate of exchange, the lack of enforceable long-term contracts, and the considerable exposure of ore and coal producers who are dependent on exports alone, make discussion among all the parties involved in the exportation of raw materials a matter of necessity.

(7) During such discussions, knowledge and information can be exchanged, and an export strategy for South African raw materials that will be in everybody's interest can be developed.

(8) The unrestrained wage and salary increases that are at present spearheaded by the gold-mining industry, in which the present gold price facilitates such increases, take no cognisance of South Africa's low productivity record, and the very considerable contribution made by wages and salaries towards production costs calls for immediate corrective measures if South Africa is to survive in the export market.

(9) A national wage and salary strategy, developed by the industry itself, is necessary since it will neither work nor be credible if it is prescribed by the State.

(10) It should be more widely realized that the error constantly being made, namely that of comparing South African salaries and wages with those of developed countries like the USA, the UK, and Germany, should be promptly rectified. South Africa is a developing country with a small percentage of developed people and a large percentage of developing people in the population. Salaries and wages in countries like Turkey, Italy, and India should be researched by a team charged with developing a salary and wage strategy that suits the specific needs of South Africa.

Acknowledgements

I gratefully acknowledge the assistance given to me by Iscor's Exploration Division and Mining Department (in particular Mr B.F. Liebenberg) and by Dr G.J. Oosthuizen in collating the data on which this address is based. In addition, I must thank my secretary for typing this address and also Iscor's Educational Technology Section for preparing the various visual aids.

Finally, I wish to express my faith in the insight and abilities of the mining people of South Africa to successfully overcome the challenges of the future.

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ADDENDUM A

FORM FOR RESERVES OF RAW AND WASHED BITUMINOUS COAL

Geological Survey, Department of Mineral and Energy Affairs
Assessment of the coal reserves of the Republic of South Africa

*Form 1: Reserves of raw and washed bituminous coal**

1. Owner ....
2. Field ....
3. Property or proposition ....
4. Block No. ....
5. Map reference ....
6. Seam ....
7. Range of thickness (m) ....
8. Range of depth (m) ....
9. Please indicate whether
   a) A commercial colliery ☐
   b) An ESCOM-tied colliery ☐
   c) An ISCOR colliery ☐
   d) A SASOL colliery ☐
   e) A prospected area only, containing a proved reserve ☐
   f) A prospected area only, containing a potential reserve ☐

Heat value MJ/kg		Below 20	20–25,5	25,5–26,5	26,5–27,5	Above 27,5
MJ/kg (actual)						
Proximate Analysis†	Moisture					
	Ash					
	Volatile matter					
	Sulphur					
Ash Analysis	SiO_2					
	TiO_2					
	Al_2O_3					
	Fe_2O_3					
	MgO					
	CaO					
	Na_2O					
	K_2O					
	P_2O_5					
	SO_3					
Ash Fusion Tempera-ture	DT					
	HT					
	FT					
Reserve of raw bituminous coal (in situ) Mt**						
Raw bituminous coal recoverable by underground mining Mt						
	Mining extraction (%)					
Raw bituminous coal recoverable by opencast mining Mt						
	Mining extraction (%)					
Washed bituminous coal$^{\phi}$ Sales tons Mt						
	Yield percentage at RD . . .					

Notes: * If a block of coal on washing yields a metallurgical fraction, complete also form 2
† Air dry basis
ϕ A high-grade steam coal obtained by a single wash—occasionally occurring as naturally high grade
** Million ton

ADDENDUM B

FORM FOR RESERVES OF METALLURGICAL COAL GENERALLY INCLUDED IN RESERVES OF BITUMINOUS COAL

Geological Survey, Department of Mineral and Energy Affairs
Assessment of the coal reserves of the Republic of South Africa

Form 2: Reserves of metallurgical coal generally included in reserves of bituminous coal*

1. Owner ....
2. Field ....
3. Property or proposition ....
4. Block No. ....
5. Map reference ....
6. Seam ....
7. Range of thickness (m) ....
8. Range of depth (m) ....

9. Please indicate whether
   - a) A commercial colliery ☐
   - b) An ESCOM-tied colliery ☐
   - c) An ISCOR colliery ☐
   - d) A SASOL colliery ☐
   - e) A prospected area only, containing a proved reserve ☐
   - f) A prospected area only, containing a potential reserve ☐

		WASHED FRACTIONAL				
Metallurgical coal yield at relative density:		..... % @ RD	..... % between RD's ... & ...	..... % between RD's ... & ...	..... % between RD's ... & ...	REMARKS
MJ/kg						
Proximate Analysis†	Moisture					
	Ash					
	Volatile matter					
	Sulphur					
	Phosphorus					
Swell index						
Roga index						
Ash Analysis	SiO_2					
	TiO_2					
	Al_2O_3					
	Fe_2O_3					
	MgO					
	CaO					
	Na_2O					
	K_2O					
	P_2O_5					
	SO_3					
Ash Fusion Temperature	DT					
	HT					
	FT					
Reserve of washed metallurgical$^{\phi}$ coal (in situ equivalent) Mt						
Washed metallurgical coal recoverable by underground mining Mt						
	Mining extraction (%)					
Washed metallurgical coal recoverable by opencast mining Mt						
	Mining extraction (%)					

Notes: * Please state whether or not this reserve is part of a reserve reported on Form 1: Yes ☐ No ☐
† Air dry basis
ϕ With reference to a block reported on Form 1—state if not

ADDENDUM C

FORM FOR RESERVES OF RAW/WASHED ANTHRACITIC COAL

Geological Survey, Department of Mineral and Energy Affairs
Assessment of the coal reserves of the Republic of South Africa

Form 3: Reserves of raw/washed anthracitic coal

1. Owner ....
2. Field ....
3. Property or proposition ....
4. Block No. ....
5. Map reference ....
6. Seam ....
7. Range of thickness (m) ....
8. Range of depth (m) ....

9. Please indicate whether
   - a) A colliery ☐
   - b) A prospected area only, containing a proved reserve ☐
   - c) A prospected area only, containing a potential reserve ☐

		RAW (in situ)	WASHED ANTHRACITE (MARKET CRITERIA)					
		A** L/M	10% max. ash	10% max. ash: low phosphorus***	10 – 12% ash	10 – 12% ash: low phosphorus	20% max. ash: 12% max. volatiles	Lean coal washed
Proximate Analysis†	Moisture							
	Ash							
	Volatile matter							
	Sulphur							
	Phosphorus							
	MJ/kg							
Ash Analysis	SiO_2							
	TiO_2							
	Al_2O_3							
	Fe_2O_3							
	MgO							
	CaO							
	Na_2O							
	K_2O							
	P_2O_5							
	SO_3							
Ash Fusion Temperature	DT							
	HT							
	FT							
Reserve of raw anthracitic coal (in situ) Mt								
Raw anthracitic coal recoverable by underground mining Mt								
	Mining extraction (%)							
Raw anthracitic coal recoverable by opencast mining Mt								
	Mining extraction (%)							
Washed* anthracitic coal Mt								
	Yield (%) at RD							

Notes: † Air dry basis
* A single wash for a higher quality commercial product
** A Anthracite L/M Lean coal
*** What you consider as low phosphorus

Analytical chemistry

The Analytical Division of the Royal Society of Chemistry is to hold SAC 89—an International Conference on Analytical Chemistry—at the University of Cambridge. This is the next in the series of triennial Conferences originally started by the Society for Analytical Chemistry (hence SAC). The Conference will be held from Sunday, July 30th, to Saturday, August 5th, 1989.

The lecture and poster sessions will be held at the Widgwick Avenue Site of the University of Cambridge, together with a book/literature exhibition. Accommodation and meals will be in King's and Queen's Colleges of this historic university.

The scientific programme will be organized around plenary, invited, and contributed papers and posters covering the whole field of analytical chemistry. As at previous Conferences, special symposia on particular analytical themes will be organized by RSC Groups and the East Anglia Region of the Analytical Division. The programme will include Workshops, where research workers can demonstrate new apparatus and techniques. Update Courses are also planned to provide all-day tutorial and practical demonstration sessions. These will be held on the Wednesday, as an alternative to scientific or cultural visits.

It is hoped that the following symposia will be included in the scientific programme:

'Electroanalysis and Sensors', organized by the Electroanalytical Group in conjunction with the Electrochemistry Group of the Faraday Division.

'Aspects of Chromatography', organized by the Chromatography and Electrophoresis Group.

'General Chemical Analysis', organized by the Micro and Chemical Methods Group.

'Food', organized by the East Anglia Region and the Food Group of the Industrial Division.

Symposia are also planned by the Atomic Spectroscopy and Chemometrics Groups.

As for previous SAC Conferences, a special issue of *The Analyst* will be published, and intending authors who would like their papers to be published are invited to include novel or relevant review materials to satisfy the normal criteria for *The Analyst*.

Enquiries should be directed to

The Secretary
Analytical Division
Royal Society of Chemistry
Burlington House
London W1V 0BN
UK.

Hoisting

For the first time since 1973, when a similar conference took place in Johannesburg, an International Conference on Hoisting—Men, Materials and Minerals will be held from 12th to 17th June, 1988, in Toronto, Ontario, Canada. The Conference is being organized under the auspices of The Canadian Institute of Mining and Metallurgy.

The purpose of this Conference is to provide a worldwide forum for the assessment of the current state of knowledge of fundamentals and of industrial practices and procedures, and to stimulate new approaches to hoisting. Its scope will include all aspects of shafts, hoists, ropes, conveyances, and headframes.

The Conference is aimed at operating, maintenance, and engineering personnel associated with equipment manufacturers, mining companies, government agencies, and universities. Although there will be an emphasis on industrial applications, it is expected that a number of papers will deal with fundamentals.

By discussing industrial applications, it is anticipated that research personnel will be stimulated to respond to the needs defined by applied research and industrial problems. Therefore, one of the principal objectives of this Conference is to encourage and facilitate the exchange of new ideas and procedures in the area of hoisting men, materials, and minerals.

All papers accepted by the technical committee will be published and bound, in full, in the Conference proceedings. This will also include papers that may not be presented during the Conference. The volume(s) will be available at the meeting, and their cost will be included in the registration fee.

A Trade Exhibition will be held concurrently with the Conference. Space for 100 booths will be available. The Planning Committee anticipate over 600 delegates from the major mining areas of North America, Europe, Africa, Asia, and Australia to attend. Thus, the Trade Exhibition will provide a means for manufacturers and service companies from these areas to display their equipment and expertise to the Conference delegates.

Enquiries should be directed to

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Montreal
Quebec H3A 2M8
Canada.
Telephone: (514) 842-3461.