FORUM FOR ECONOMICS AND ENVIRONMENT
CONFERENCE 2002, CAPE TOWN

THE EXTERNALITY COST OF COAL COMBUSTION IN SOUTH AFRICA[1]

J.N. BLIGNAUT

UNIVERSITY OF PRETORIA
DEPARTMENT OF ECONOMICS

N.A. KING

CSIR
ENVIRONMENTEK

[1] Paper presented at the first annual conference of the Forum for Economics and Environment. The authors would like to thank Dr A Kenny (ERI) for assistance and Prof P Lloyd (ERI), Mr R Spalding-Fecher (EDRC), Dr M de Wit (CSIR), Dr R Mirrilees (Nathan Associates) and Ms G Downes (ESKOM) for their elaborate comments. Remaining errors and views expressed are that of the authors and do not reflect those of any institution that they may be involved with.

ABSTRACT

South Africa is endowed with an abundance of coal, which, subsequently, has provided the economy with a major source of energy from which diversification into a strong manufacturing sector could be supported. The use of coal does, however, cause various environmental damages due to pollution externalities and emissions; these are impacts that place strains and limitations on the use of other natural assets beyond the mere extraction thereof. These social costs have not been internalised by industry though and therefore this paper examines the cost of these environmental externalities that arise through the combustion of coal by South African industries. Though the paper alludes to the local impact of volatile matter and sulphur, the focus is on the cost of carbon dioxide and methane emissions. It is concluded that the monetary values of these externalities are significant and that the environmentally inclusive price (including negative environmental externalities) of coal is appreciably higher than the private or market price thereof paid by each respective industry.

KEY WORDS

Coal consumption

Combustion of coal

Coal mining externalities

Damage cost of greenhouse gas emissions

Social cost of externalities

THE EXTERNALITY COST OF COAL COMBUSTION IN SOUTH AFRICA

1 INTRODUCTION

South Africa is endowed with an abundance of coal, which, subsequently, has provided the economy with a major source of energy from which diversification into a strong manufacturing sector could be supported. The use of coal does, however, cause various environmental damages due to pollution externalities; these are impacts that place strains and limitations on the use of other natural assets beyond the mere extraction thereof. These externality effects have been well captured in a number of previous studies (Van Horen 1994, Spalding-Fecher 2001 and Spalding-Fecher and Matibe 2001).

Conventional pricing methods do not account for the full economic cost associated with the extraction and use of coal (especially the externality effects caused by combustion), potentially contributing to a misallocation of resources. To determine the full economic cost requires the calculation of a price for coal inclusive of the externality effects by using (i.e. burning) coal. This paper works towards this end in estimating a price for coal internalising the damage cost caused by carbon dioxide (CO_2) and methane (CH_4) emissions due to its contribution to climate change. Reference to local pollutants such as sulphur dioxide (SO_2), ash and volatile matter and their respective health impacts will be made, but no cost will be assigned to them. The impact of these emissions on water quality is also not internalised. Given these omissions, the values presented here reflect a lower bound estimate of the environmentally inclusive price (a price for coal inclusive of the negative environmental externalities) for coal per sector.

It is acknowledged that all South African industries do have significant positive impacts as well, such as production and employment. These benefits are, however, properly accounted for through conventional accounting methods. Unaccounted positive externalities due to the use of coal, such as the benefits of increased electrification during the period 1994-2000 under the Reconstruction and Development Programme, has also been documented (Spalding-Fecher and Motibe 2001). This study does not present the value of these since it is done for only one sector, namely electricity. Furthermore, in the previous studies mentioned the social cost of negative externalities was expressed in terms of the price of electricity and not the source of the emissions, namely coal. It is argued here that the externality cost of coal combustion should be relayed to the price of coal and not to the commodity or product produced (as conventionally done) since it obscures the fact that there might be other technologies than coal combustion for the generation of energy. In relaying the negative environmental effects of coal combustion directly to the commodity, one almost accept that there is no alternative to coal combustion and that the only way to mitigate or express the problem is by a change in the product or commodity price. This is clearly wrong. When alternative sources of energy are investigated, the appropriate price for coal in the cost benefit analysis should be the price inclusive of its negative environmental impacts.

In answering the stated question (the externality cost of coal combustion), this paper investigates the South African coal production and consumption markets in the next section. Section 3 concentrates on the theory justifying the internalisation of externalities followed by a section calculating the damage cost of carbon dioxide and methane due to their contribution to climate change. Lastly, though this paper is limited in its scope, some tentative conclusions could be drawn.

2 COAL CONSUMPTION IN SOUTH AFRICA

South Africa is the sixth largest producer and second largest exporter of hard coal in the world, beaten only by Australia in the exports market for 2000 (see Table 1). In 2000 the total value of the export earnings of coal sales was approximately R11 230 million or 56 per cent of the total value of coal sales (see also Table 3), though in volume terms exports only represent approximately 31 percent of the total production. Coal's apparent abundance (with reserves lasting more than a 100 years at current extraction rates (Blignaut and Hassan 2001)) coupled with relatively low coal prices (see Table 2) have encouraged the development of many energy-intensive industries, including the mining of non-energy minerals, manufacturing and electricity generation within the country (C.O.M. 2000). These represent positive externalities of having access to low cost coal and a lot of it.

Table 1: Producers, importers and exporters of coal: 2000

Producers	Hard coal (Mt)	Brown coal (Mt)	Importers of hard coal	(Mt)	Exporters hard coal	(Mt)
People's Rep. of China	1 171	*	Japan	133	Australia	170
United States	899	77	Korea	55	**South Africa**	**69**
India	310	22	Chinese Taipei	41	United States	57
Australia	238	68	Germany	22	Indonesia	55
Russia	169	86	United Kingdom	21	People's Rep. of China	37
South Africa	**225**	**0**	Spain	20	Canada	34
Germany	37	168	Netherlands	19	Colombia	30
Poland	101	59	India	18	Russia	28
DPR of Korea	67	24	France	17	Poland	24
Ukraine	81	1	Italy	17	Kazakhstan	16
Rest of the World	338	390	Rest of the World	176	Rest of the World	30
World	3 637	895	**World**	539	**World**	550

IEA 2001.

Table 2 Retail price: Steam coal for industry: 2000

	US$/t
Germany	144,5
France	78,74
Korea	53,35
United Kingdom	49,58
Italy	41,97
Poland	37,35
United States	34,81
Portugal	34,61
Turkey	32,92
India	14,66
Czech Republic	14,3
South Africa	**10,38**
Slovak Republic	6,3

IEA 2001.

Electricity generation is one of the industries benefiting the most from the large coal reserves and the relatively cheap production thereof. ESKOM is by far the largest single producer of electricity in South Africa, and is currently the fifth largest electricity utility in the world in terms of both sales and capacity (ESKOM 1999). Not only is it such a large producer of electricity, its share in domestic production has also increased considerably since 1960. In 1960 ESKOM produced 62,3 per cent of the total electricity and 98,3 per cent in 1999, mainly through its coal-fired power stations. In 1960, all of the electricity produced was coal-based, but due to other technologies such as nuclear power, coal's contribution declined slightly to approximately 93 per cent in 1999. Consequently, ESKOM is the largest single consumer of coal in South Africa, absorbing approximately 41 per cent of the total coal production in 2000 (approximately 60 per cent of the domestic market). Its consumption of coal increased more than seven fold over the period under consideration from 12,5 million tonnes to 91,8 million tonnes in 2000. For comparative purposes, this consumption of coal should be seen in the light of the fact that total coal exports comprised 31 per cent of the market in the same year (see Blignaut and De Wet 2001). Table 3 provides a breakdown of the consumption of coal per industry in 2000.

Table 3 Coal sales by sector: 2000

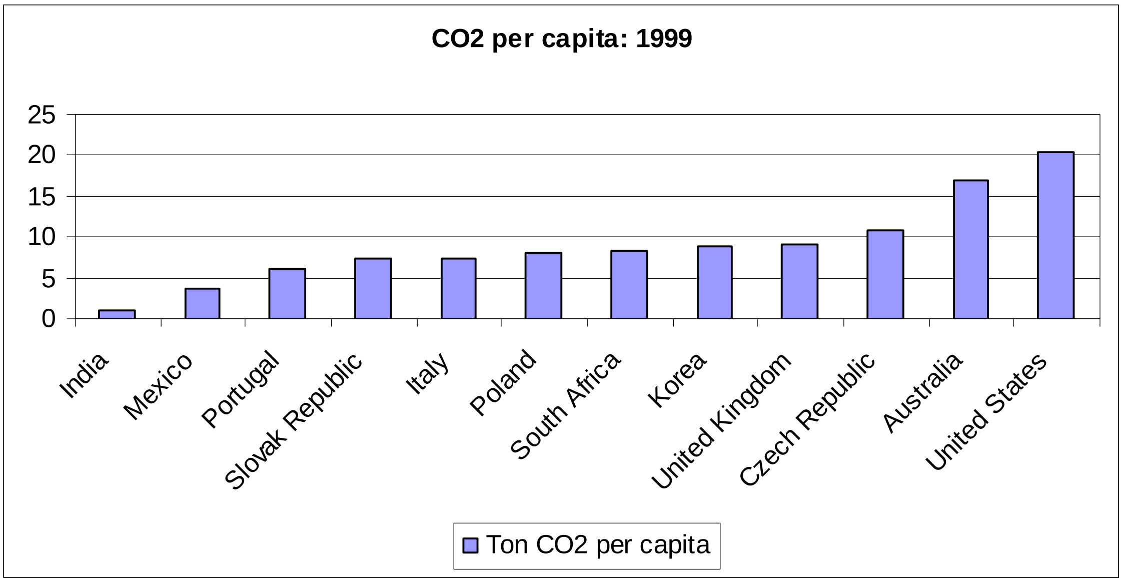
	Mass (t)	% share	Value (R'000)	% share	Price (R/t)
ISCOR	1 583 865	0,71	378 669	1,89	239,08
Metallurgical	1 272 014	0,57	190 016	0,95	149,38
Agriculture	69 053	0,03	7 471	0,04	108,19
Iron and Steel	2 881 311	1,29	2 98 751	1,49	103,69
Industries	2 630 809	1,17	258 464	1,29	98,25
Chemical Industries	1 080 816	0,48	105 575	0,53	97,68
Merchants and Domestic	3 920 241	1,75	374 600	1,87	95,56
Gold and Uranium Mines	24 043	0,01	2 232	0,01	92,83
Other Mining	120 998	0,05	10 565	0,05	87,32
Water	146 534	0,07	11 946	0,06	81,52
Synthetic Fuels (SASOL)	46 334 788	20,67	2 845 540	14,23	61,41
Cement and Lime	1 071 221	0,48	65 532	0,33	61,17
Electricity (Non-ESKOM)	1 556 304	0,69	95 126	0,48	61,12
ESKOM	91 811 056	40,96	4 129 021	20,64	44,97
Brick and Tile	176 517	0,08	7 525	0,04	42,63
Exports	69 456 361	30,99	11 230 234	56,14	161,69
Total	**224 135 931**	**100**	**20 002 544**	**100**	**56,77**

DME 2001.

From the above it should be clear that the coal industry is an important one in the South African economy, both for domestic downstream economic activity and earner of international exchange. Many of the industries listed above would never have been able to develop to the extent that they have if it had not been for the availability of coal. But, as stated above and clearly evident from Tables 2 and 3, the price of coal varies significantly among sectors, with ESKOM, comprising 60 per cent of the domestic market, paying very low prices, also when compared internationally. The low price of coal can be attributed to the low quality of coal, the fact that ESKOM owns its own coal mines, and bulk purchases of coal.

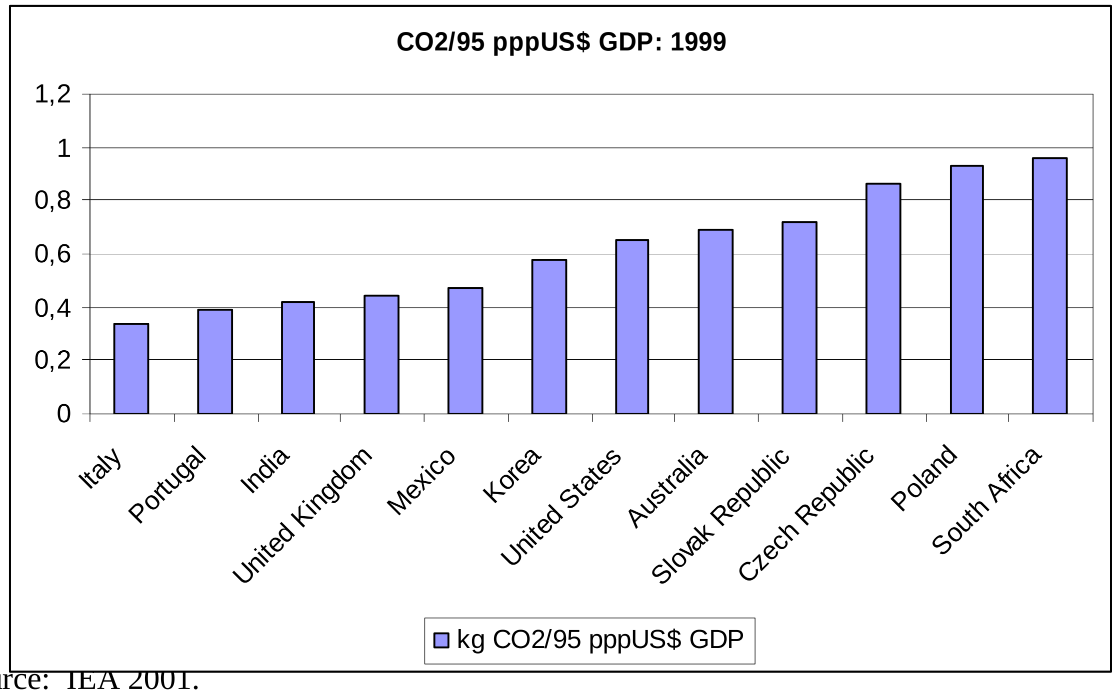
The low price of coal, however, stimulates consumption of coal across all sectors rather than conserving it (Doppegieter *et al.* 1998 and 1999). Consuming low-quality coal, however, has its major disadvantage in the form of emissions, which coincide with the combustion process. In 1999 South Africa contributed 1,6 per cent towards global CO_2 emissions and expressed in terms of per capita and per purchase power parity adjusted GDP (or emissions intensity), South Africa's emissions are amongst the highest in the world, as shown in Figures 1 and 2 below (IEA 2001). South Africa, being a developing and a non-annex 1 country is not obliged to reduce its carbon emissions, but from the evidence shown here its carbon footprint are amongst the highest in the world and it would therefore be of strategic importance to consider options to reduce the emissions load before it will have to do so at high cost later.

Figure 1



Source: IEA 2001.

Figure 2



Source: IEA 2001.

But what is the social and environmental cost of these emissions, which is not captured in the market price for coal? This is the subject of the next section.

3 COAL MINING EXTERNALITIES

Free markets, theoretically, provide goods and services, resolve shortages and surpluses, and eliminate inefficiencies through the pricing mechanism and thereby lead to the socially efficient allocation of resources without the intervention of government action (Callan *et al*. 2000; Khan 2000). The role of this *invisible hand* postulates that in the seeking of their own selfish goals, consumers and producers unknowingly make decisions that improve the well being of society. Evidently, the efficiency with which markets function is paramount to the sustainability and improvement of society's overall welfare, however, the conditions for such market efficiency is very strong and a long list of possible sources for market failure exist, namely:

- poorly defined property rights,
- the existence of spill-over effects or externalities,
- pervasive and high transaction costs,
- barriers to market entry and trade,

- short-sightedness to current global and local needs,
- high levels of uncertainty and risk associated with the transaction,
- irreversibility of transactions,
- absence, weak or corrupt institutions such as the government,
- failure to assign representative prices to the resource, and
- the nature of the good, such as public goods or communal resources[2].

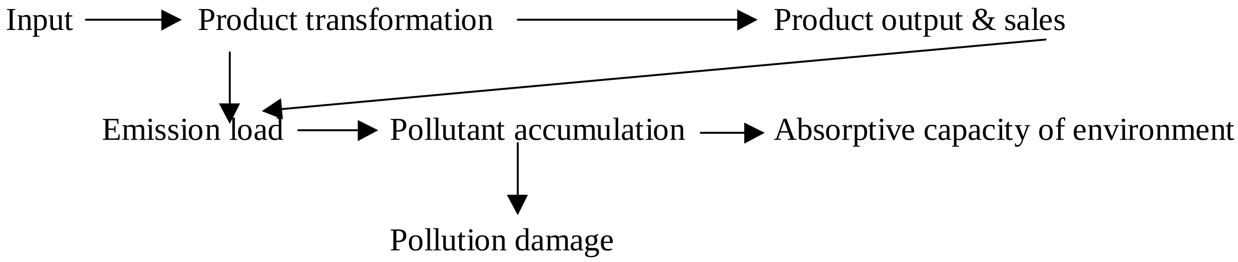
Intrinsic to the process of production, consumption and the well-functioning market, is the acknowledgement that materials in some form are used as inputs in the commodity process. These inputs are invariably sourced from the natural environment. The economic process is dependent on natural resources, which in turn adhere to the fundamental laws of the natural sciences. The law of mass balance implies that:

… the mass of matter that is used as an input into an activity, must be equivalent to the mass of matter that results in the output activity. Any changes in mass that occur during the transformation process, resulting in an output mass lower than an input mass are attributable to waste (Kahn 2000).

Economic activity, in the fuller context of materials balance, gives rise to residuals or wastes that may damage the existing natural resource base when released into the environment. A prime example of an economic activity solely dependent on natural resources, is that of mining. Minerals frequently lie in forms and structures that make them difficult to extract and process, consequently, many by-products in various forms of waste are generated. An example of the flow of energy is shown in Figure 3.

[2] For a more comprehensive discussion on market failure see Tietenberg (1992).

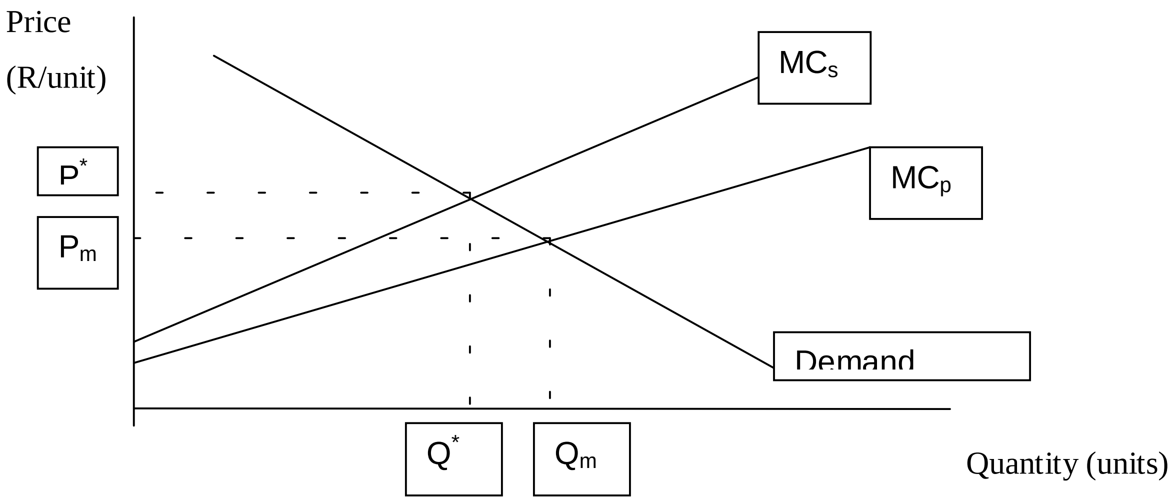
Figure 3 Relationship between input, production and pollution



Adapted from: Tietenberg 1992.

Market failures, due to the non-incorporation of environmental related impacts, contribute to a disparity between the private costs and social costs associated with the use of any commodity, i.e. coal, as shown in Figure 4 below.

Figure 4 Market allocation with pollution



Source: Tietenberg 1992.

Using any commodity without internalising its social costs will result in the misallocation of resources. In the example above illustrated by Figure 4, the demand for a product is indicated by the demand curve. Without internalising any polluting effects, the producing firm will only have a marginal private cost curve (MC_p). Internalising any social cost that coincide with the production of the product, society will have a marginal social cost curve (MC_s) which includes both social and private costs and is hence laying at a higher level than the MC_p curve. A number of conclusions can be drawn from Figure 4, namely:

- the output of the commodity is too large ($Q_m > Q^*$),

- the price of the product is too low ($P_m < P^*$),
- as long as costs are external there is no incentives to produce less pollution per unit of output,
- hence too much pollution is produced,
- recycling and reuse of polluting substances are discouraged since release into the environment is too cheap (Tietenberg 1992:47-48).

The question that arises is: What is the social cost assigned to the use of coal?

4 THE CLIMATE CHANGE COST OF COAL COMBUSTION

4.1 Research method and data

The tonnes of coal produced and disaggregated by sector of demand for 2000 were obtained from the Minerals Bureau, South Africa (DME 2001 - see also Table 3). To quantify the volume of sulphur dioxide (SO_2), methane (CH_4), carbon dioxide (CO_2), ash and volatile matter various conversion factors were used and applied to the volume of coal purchased in 2000 by each of the sectors.

The conversion factor for SO_2 was obtained by calculating the sulphur (S) content in the coal using the percentages as in Pinheiro *et al.* (1997) (see Annexure A) and weighing it with the 2000 consumption levels of either anthracite or bituminous per sector and multiplies the total volume of sulphur by a factor of 2 to determine the weight of SO_2. The atomic weight of sulphur is 32 and that of oxygen 16, therefore the total atomic weight of SO_2 is 64 and 64/32 equal 2 and hence the multiplication factor.

The conversion factor for methane was determined from the IPCC 1996 guidelines of 0,7kg of CH_4 per TJ coal, which transcribes to 24,7 kg CH_4 per tonne of coal. A conversion factor for CO_2 was obtained by calculating the carbon content in the coal using Pinheiro *et al.* (1997) and multiplying the total volume of carbon by 3,667 to determine the weight of CO_2 in a similar way as has been done for SO_2. The atomic weight of carbon is 12 and that of oxygen 16, therefore the total atomic weight of CO_2 is 44 and 44/12 equal 3,667. The ash and volatile matter content of the coal purchased by each industry has been calculated in the same way using the percentages as determined by Pinheiro *et al.* (1997).

While the volumes of sulphur, ash and volatile matter have been calculated, the social cost associated with their emissions are not since they are local pollutants and the damage caused by these pollutants depends very much on the demographic composition of the exposed population, level of exposure and dose-response functions. This study only quantifies the damage cost of the global pollutants, CO_2 and CH_4, in their contribution to global climate change.

Sandor (2001) estimates the price for CO_2 in 2000 between US$5/tonne and US$10/tonne. For this analysis a conservative $2,50/tonne and $5,00/tonne are used. The price for methane was derived from those for carbon dioxide based on the widely accepted principle of 1 tonne CH_4 that has the same global warming potential as 21 tonnes carbon dioxide, hence multiplying the price for carbon dioxide by 21 to determine the price for CH_4, namely US$52,5/tonne and US$105/tonne respectively.

The Rand values for the global damage cost were obtained adjusting the dollar price using the 2000 exchange rate (since all the prices and volumes were for 2000), namely R6,9353/$ and multiplying by the tonnes produced for each respective industry. This implies a price of R17,34/tonne or R34,68/tonne for CO_2 and R364,1/tonne and R728,21/tonne for CH_4.

4.2 Research results

The volume of S, SO_2, CH_4 and CO_2, ash and volatile matter produced by each industry based on the volume of coal combusted in 2000 are displayed in Table 4 below. It should be noted that the export sector is not shown since it is unknown how the coal is used in the various countries of their destination. Another important aspect is the fact that the emissions of the two main consumers of coal, namely ESKOM and SASOL, have been verified against their own published emissions as per their respective environmental reports for 2000 (ESKOM 2001 and SASOL 2001b). The totals shown in the last row is inclusive of the figures of these two companies and not that which has been calculated. Interesting to note also that for both ESKOM and SASOL the coal consumed according to their figures is more than what is reported by the Department of Minerals and Energy.

From this calculation a total of 2,084 million tonnes SO_2, 3,820 million tonnes CH_4, 252,345 million tonnes of CO_2, 39,190 million tonnes of ash and 5,192 million tonnes of volatile matter are produced by industries using coal in 2000.

ESKOM emitted 1,78 million tonnes SO_2 using the formula described above, which over estimated the emissions by approximately 15 per cent since ESKOM estimates its emissions as being 1,505 million tonnes. Given a total emission of 2,084 million tonnes ESKOM are producing 72 per cent of the county's sulphur dioxide. SASOL's contribution of 293 kiloton is 14 per cent of the total SO_2 load. The calculated figure for SASOL is, however, almost three times higher, namely 899 kiloton.

Regarding CO_2 emissions, the picture is reversed. According to the calculations here, ESKOM emitted 143 million tonnes of carbon dioxide, ESKOM itself estimate their emissions to be 161,2 million tonnes (ESKOM 2001) or 64 per cent of the total CO_2 emissions from industry. This represents an underestimation of 11 per cent by the formula. With regard to SASOL, the calculated figure[3] (taking into account that not all the coal is combusted in boilers but some goes into a chemical gasification process) CO_2 emissions are 66,3 million tonnes and represent an 11 per cent overestimation compared to SASOL's own estimate of 57,7 million tonnes, which are 23 per cent of the total CO_2 emissions by industry. All other industries are therefore responsible for only 13 percent of the CO_2 emissions, which relates very well to the fact that they consume only 10,3 per cent of the coal.

Regarding ash, the formula and ESKOM and SASOL's own estimates are closely related as well. ESKOM estimates its ash production at 24,6 million tonnes (63 per cent of the total) while the formula estimated it to be 27,8 million tonnes (an 11 per cent overestimation) where SASOL estimates its ash production at 11,8 million tonnes (30 per cent of the total) and the formula estimated it to be 12,5 million tonnes (an overestimation of 6 per cent). The formula was, however, particularly weak in estimating volatile matter and all the numbers should be treated with caution.

As discussed before, the damage and health impacts of the local pollutants SO_2, ash and volatile matter have not been cost, nor has the change in surface and ground water quality as a

---

[3] The calculated figure for SASOL's CO_2 emissions are based on calculations by Prof P Lloyd (2002) of the ERI.

result of these emissions been quantified since they require site specific data. With regard to ESKOM and electricity generation Van Horen (1996) and Spalding-Fecher and Motibe (2001) has done some work in this regard. This study focuses on calculating the damage cost due to the emission of the global pollutants CO_2 and CH_4 due to their contribution to climate change. These calculations are shown in Tables 5 and 6 below.

Table 4 Volume of emissions per sector based on volume coal purchased: 2000

	Coal consumed	Weighted: sulphur content [a]	Sulphur [b]	S to SO_2 [c]	SO_2 [d]	CH_4 [e]	CH_4 [f]	Weighted: carbon content [g]	Carbon [h]	C to CO_2 [i]	CO_2 [j]	Ash [k]	Volatile matter [l]
	t	%	t	Conversion factor	t	kg/ton of coal	t	%	t	Conversion factor	t	t	t
ISCOR	1 583 865	0,8999	14 253	2	28 506	24,7	39 121	55,02	871 493	3,667	3 195 475	257 034	405 262
Metallurgical	1 272 014	0,82	10 431	2	20 861	24,7	31 419	63,56	808 502	3,667	2 964 507	115 544	258 381
Agriculture	69 053	0,8207	567	2	1 133	24,7	1 706	56,26	38 849	3,667	142 447	10 396	17 624
Iron and Steel	2 881 311	0,82	23 627	2	47 254	24,7	71 168	56,12	1 617 010	3,667	5 929 036	469 284	739 914
Industries	2 630 809	0,8998	23 672	2	47 344	24,7	64 981	55,1	1 449 658	3,667	5 315 411	425 711	671 213
Chemical Industries	1 080 816	0,8991	9 718	2	19 435	24,7	26 696	55,72	602 235	3,667	2 208 196	171 011	269 631
Merchants and Domestic	3 920 241	0,8254	32 358	2	64 715	24,7	96 830	56,67	2 221 637	3,667	8 146 003	577 948	979 832
Gold and Uranium Mines	24 043	0,9	216	2	433	24,7	594	54,9	13 200	3,667	48 399	3 919	6 179
Other Mining	120 998	0,9	1 089	2	2 178	24,7	2 989	54,9	66 428	3,667	243 569	19 723	31 096
Water	146 534	0,82	1 202	2	2 403	24,7	3 619	56,2	82 352	3,667	301 958	23 885	37 659
SASOL (calculated)	46 334 788	0,97	449 447	2	898 895	24,7	1 144 469	39,03[n]	18 086 362	3,667	66 316 667	12 510 392	10 610 666
SASOL (Own figures[m])	51 800 000				293 000		1 144 469[p]				57 713 000	11 841 000	1 025 000
Cement and Lime	1 071 221	0,9	9 641	2	19 282	24,7	26 459	54,9	588 100	3,667	2 156 368	174 609	275 304
Electricity (Non-ESKOM)	1 556 304	0,97	15 096	2	30 192	24,7	38 441	42,5	661 429	3,667	2 425 240	471 560	364 175
ESKOM (calculated)	91 811 056	0,97	890 567	2	1 781 134	24,7	2 267 733	42,5	39 019 699	3,667	143 072 229	27 818 750	21 483 787
ESKOM (Own figures[o])	92 300 000				1 505 000		2 267 733[p]				161 200 000	24 600 000	66 080
Brick and Tile	176 517	0,9	1 589	2	3 177	24,7	4 360	54,9	96 908	3,667	355 329	28 772	45 365
Total (Only own figures)	**160 633 726**				**2 084 913**		**3 820 585**				**252 344 938**	**39 190 396**	**5 192 715**

a: Pinheiro *et al.* 1997 (see Annexure A) percentages applied to 2000 production from DME 2001. b: Calculated. c: Discussed in text. d: Calculated.
e: Discussed in text. f: calculated. g: Pinheiro *et al.* 1997 (see Annexure A) percentages applied to 2000 production from DME 2001. h: Calculated.
i: Discussed in text. j: Calculated. k: Discussed in text. l: Discussed in text. m: SASOL 2001b. n: Effective weight after taking chemical extraction process into account.
o: ESKOM 2001. p: Not published, taken from calculated figures.

The volume of CO_2 and CH_4 as per Table 4 have been multiplied by the prices associated with each as discussed above and the results are shown in Table 5.

Table 5 The cost of emissions: 2000

	Coal purchased	CH_4			CO_2			Total	
	t	t	R364,1 / tonne	R728,21 / tonne	t	R17,34 / tonne	R34,68 / tonne	Lower scenario	Higher scenario
			R millions	R millions		R million	R million	R million	R million
ISCOR	1 583 865	39 121	14	28	3 195 475	55	111	70	139
Metallurgical	1 272 014	31 419	11	23	2 964 507	51	103	63	126
Agriculture	69 053	1 706	1	1	142 447	2	5	3	6
Iron and Steel	2 881 311	71 168	26	52	5 929 036	103	206	129	257
Industries	2 630 809	64 981	24	47	5 315 411	92	184	116	232
Chemical Industries	1 080 816	26 696	10	19	2 208 196	38	77	48	96
Merchants and Domestic	3 920 241	96 830	35	71	8 146 003	141	283	177	353
Gold and Uranium Mines	24 043	594	0	0	48 399	1	2	1	2
Other Mining	120 998	2 989	1	2	243 569	4	8	5	11
Water	146 534	3 619	1	3	301 958	5	10	7	13
SASOL (calculated)	46 334 788	1 144 469	417	833	66 316 667	1 150	2 300	1 567	3 133
SASOL (Own figures)	51 800 000	1 144 469	417	833	57 713 000	1 001	2 001	1 417	2 835
Cement and Lime	1 071 221	26 459	10	19	2 156 368	37	75	47	94
Electricity (Non-ESKOM)	1 556 304	38 441	14	28	2 425 240	42	84	56	112
ESKOM (calculated)	91 811 056	2 267 733	826	1651	143 072 229	2 481	4 962	3 307	6 613
ESKOM (Own figures)	92 300 000	2 267 733	826	1651	161 200 000	2 795	5 590	3 621	7 242
Brick and Tile	176 517	4 360	2	3	355 329	6	12	8	15
Total (Only own figures)	160 633 726	3 820 585	1 391	2782	252 344 938	4 376	8 751	5 767	11 534

Source: Own analysis.

Based on the higher price, the total cost of methane and carbon dioxide externalities was calculated as R11 534 million (1,3 per cent of GDP in 2000) of which carbon dioxide contributed R8 751 million or 76 per cent. Should one use $7,5 per tonne of carbon the total cost will be R17 298 million or 2 per cent of GDP of which CO_2 contributed R13 125 million.

The main contributor to this externality cost is ESKOM's CO_2 emissions, contributing R5 590 million in damage or 64 per cent of the total and SASOL with R2 001 million. ESKOM's turnover for 2000 was R24 459 million (ESKOM 2000) and that of SASOL R25 762 million (SASOL 2001a). This implies that ESKOM's contribution to the pollution externalities calculated here (R7 242 million) is equivalent to 30 per cent of its turnover and that of SASOL (R2 835 million) less than half of that of ESKOM, namely 11 per cent. The damage cost of CO_2 calculated here (R5 590 million) falls between the lower and central scenario calculated by Spalding-Fecher and Motibe (2001). According to them the lower scenario is

R1 723 million and the central scenario is R7 467 million for 1999, using a completely different research method.

Table 6 shows a comparison between the social or externality cost of air pollution (only the two global pollutants) with that of the private cost or market prices of coal.

Table 6 Comparative externality prices and market prices: 2000

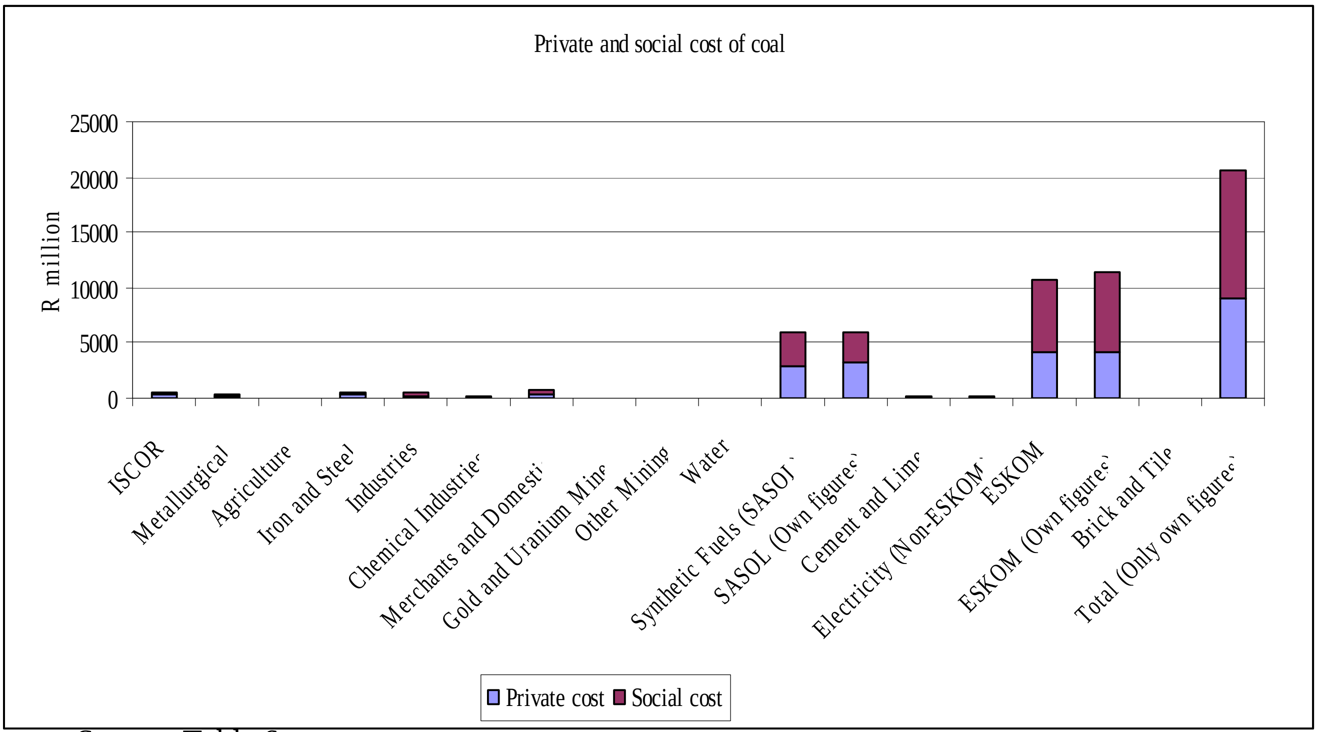
	Volume of coal purchased	Total private cost	Average private price	Social cost[b]	Social cost as % of private cost	Total private & social cost	Average private & social price	Difference: Total prvte & social price & private price
	t	R million	R/t	R million	%	R million	R/t	R/t
	a	b	c	d	d/b = e	b+d = f	f/a = g	f-b = h
ISCOR	1 583 865	379	239,08	139	37	518	327,03	87,95
Metallurgical	1 272 014	190	149,38	126	66	316	248,19	98,81
Agriculture	69 053	7	108,19	6	83	14	197,72	89,53
Iron and Steel	2 881 311	299	103,69	257	86	556	193,04	89,35
Industries	2 630 809	258	98,25	232	90	490	186,30	88,05
Chemical Industries	1 080 816	106	97,68	96	91	202	186,52	88,84
Merchants and Domestic	3 920 241	375	95,56	353	94	728	185,71	90,15
Gold and Uranium Mines	24 043	2	92,83	2	95	4	180,64	87,81
Other Mining	120 998	11	87,32	11	101	21	175,12	87,80
Water	146 534	12	81,52	13	110	25	170,97	89,45
Synthetic Fuels (SASOL)	46 334 788	2 846	61,41	3 133	110	5 979	129,05	67,64
SASOL (Own figures)[a]	51 800 000	3 181	61,41	2 835	89	6 016	116,14	54,73
Cement and Lime	1 071 221	66	61,17	94	144	160	148,97	87,80
Electricity (Non-ESKOM)	1 556 304	95	61,12	112	118	207	133,15	72,03
ESKOM	91 811 056	4 129	44,97	6 613	160	10 742	117,00	72,03
ESKOM (Own figures)[a]	92 300 000	4 151	44,97	7 242	174	11 393	123,43	78,46
Brick and Tile	176 517	8	42,63	15	206	23	130,43	87,80
Total (Only own figures)	**160 63 3726**	**9 139**	**56,89**	**11 534**	**126**	**20 672**	**128,69**	**71,80**

Source: Own analysis.

Notes: a: The value of private cost has been calculated using the average price per tonne as per DME and multiply that to the volume provided. b: Only the cost of CO_2 and CH_4 emissions, from Table 5.

From column e in Table 6 it is evident that private cost exceeds social cost only in a few industries. Remarkably it is also those industries which pay a higher average price for their coal (column c). The social cost of ESKOM is almost double its private cost and these two costs are almost equivalent for that of SASOL. For all industries the total private cost was R9 139 million, but the social cost R11 534 or 26 per cent higher than that of the private cost. Combined, the total private and social cost is R20 672 million (column f in Table 6) see also Figure 5.

Figure 5



Source: Table 6.

Using the total private and social cost an average price for coal per sector has been calculated internalising the externality costs (column g). These values are considerably higher than that of the private cost only (column c) and the difference between the total private and social cost per tonne of coal and the private price is given in column h. From this it is clear that the environment and society subsidies industry on average by R71,80 per tonne of coal (R128,69 - R56,89). For example ESKOM is currently paying an average of R44,97/tonne, including its externality cost, the price should be R123,43/tonne, implying a difference of R78,46/tonne and SASOL is been subsidised by society and the environment to the extent of R54,73/tonne.

5 CONCLUSION

From this study it has been established that the social cost of combusting coal, isolating only its contribution to climate change through the emission of greenhouse gasses, is substantial, with the social cost on average more than double the market price for coal. These estimates represent a lower-bound estimate of the social cost due to the exclusion of the health impacts of local pollutants on people and the impact they have on water and land quality. Though a comprehensive discussion of the implications of these estimates is not the subject of this study, one can draw some early conclusions.

Should the full social costs be internalised, the cost structures of all the industries using coal and those industries that depend on the coal combusting industries would be severely influenced. The economy-wide impact will therefore be substantial and the economy is not ready for such integration. Fact is, however, the environment and society is subsidising the coal combusting industries on average by an amount more than the private cost of coal.

As stated in the introduction, it is conceptually better to relay the social cost of the use of coal to its price and calculate an environmentally inclusive price thereof than expressing it as a price change to the output of a particular sector. Doing so the principles of a life-cycle analysis are upheld since a change in the price of the input will lead to a change in the output price. Should the demand for the output then changes as a consequence, the need would arise to use less of the input or to use it more efficiently.

The magnitude of the environmentally inclusive price of coal calculated here suggests also that in deciding whether to turn to cleaner technologies or not, one should not look at the private cost or market price of coal alone, but factor the cost of these, and other, externalities into the equation as well. A cost benefit analysis which considers alternative sources for energy generation than coal combustion which not be able to compete at an average price of R56,89 (average market price) might become viable at an average price of R128,69 (price of coal inclusive of its contribution to global pollution). The pay-back period on introducing the new technologies may be surprising short as well, as noted by Hawken ***et al.*** (2000).

LIST OF REFERENCES

Blignaut, J.N. and De Wet, T. 2001. Some recommendations towards reducing electricity consumption in the South African manufacturing sector. *South African Journal of Economic Management Sciences,* 4(2):359-379.

Blignaut, J.N. and Hassan, R.M. 2001. A natural resource accounting analysis of the contribution of mineral resources to sustainable development in South Africa. *South African Journal of Economic Management Sciences,* supplement series 3:1-39.

Callan, S.J.and Thomas, J.M. 2000. *Environmental Economics and Management: Theory, Policy and Applications*. Chapter 3, pp 67 – 104.

Chamber of Mines of South Africa (C.O.M.). 2000. *Annual Report 1999/2000*.

Department of Minerals and Energy (DME). 2001. Unpublished data provided by Prévost, X.

Doppegieter, J.J., Du Toit, J. and Liebenberg, J. 1998. *Energy Futures 1998/99*. Stellenbosch: Institute for Futures Research.

Doppegieter, J.J., Du Toit, J. and Liebenberg, J. 1999. *Energy Indicators 1999/2000*. Stellenbosch: Institute for Futures Research.

ESKOM. 1999 *Annual Report*. 1999. Johannesburg. ESKOM. (www.eskom.co.za/main.asp?curl=publications.html)

ESKOM. 2000 *Annual Report*. 2000. Johannesburg. ESKOM http://www.eskom.co.za/annreport01/home.htm.

ESKOM. 2001. *Environmental report 2000*. Johannesburg. ESKOM. http://www.eskom.co.za/enviroreport01/air.htm.

Fuggle, R. F. and M. A. Rabie. 1999. *Environmental Management in South Africa*. Chapter 15 and 16. Pp 337 – 381. Juta and Co, Ltd, Cape Town.

Hawken, P, Lovins, A.B. and Lovins, L.H. 2000. *Natural Capitalism*. Earthscan.

International Environmental Agency (IEA). 2001. *Key world energy statistics*. Paris: IEA. (www.iea.org/statist/key2001/keyworld-2001.pdf)

Khan, J. R. 2000. *The Economic Approach to Environmental and Natural Resources* (2nd ed.). The Dryden Press, New York. Chapter 9, pp 257 – 282.

Pinheiro, H.J., Boshoff, H.P. And Pretorius, C.C. 1997. *Analysis of coal product samples of producing South African collieries*. Pretoria: CSIR.

Prévost, X. 2001. DME. Personal communication.

Sandor, R. 2001. How I see it: The Case for Coal. *Environmental Finance*. March, p. 12.

SASOL. 2001a. *Annual Report*. 2001. Johannesburg. SASOL. http://www.sasol.com/annual2001/pdf/sasol_financials.pdf.

SASOL. 2001b. *Environmental report 2000*. Johannesburg: SASOL. http://www.sasol.com/downloads/pdf/environment/envan2001sec.pdf.

Spalding-Fecher, R. 2001. Health benefits for electrification in developing countries: a quantitative assessment in South Africa. Working paper submitted to *Environmental and Development Economics*, EDRC: Cape Town.

Spalding-Fecher, R. and Matibe D.K. 2001. *Electricity and externalities in South Africa*. Working paper: EDRC: Cape Town.

Tietenberg, T. 1992. *Environmental and Natural Resource Economics*. Harper Collins Publishers Inc.

Van Horen, C. 1996. *Counting the Social Costs: Electricity and Externalities in South Africa*. Cape Town: Elan Press and UCT Press.

Annexure A Weighted analysis for coal products used in the main consumption sectors: 1996

Consumption sector	Mt	AIR-DRY BASIS						
		Calorific value MJ/kg	[1] Gross Calorific value MJ/kg	Moisture %	Ash %	Volatile matter %	Fixed carbon %	Total sulphur %
Export: Anthracitic	2,13	30,85	30,75	2,0	11,3	8,6	78,1	1,06
Bituminous:								
Metallurgical	1,86	30,72	30,66	2,7	7,4	31,7	58,2	0,58
Steam	55,15	27,88	27,82	2,9	13,5	26,7	56,9	0,63
Electricity: Bituminous	81,95	20,46	20,37	3,8	30,3	23,4	42,5	0,97
Synfuel: Bituminous	45,64	21,19	21,10	4,7	27,0	22,9	45,4	0,97
Industry: Anthracitic	0,09	31,33	31,25	2,2	9,4	5,5	82,9	0,87
Bituminous	5,74	26,50	26,41	3,1	16,3	25,7	54,9	0,90
Mettalurgic: Anthracitic	0,36	31,18	31,10	2,3	9,6	5,8	82,3	0,82
Bituminous	6,69	28,53	28,45	2,8	12,7	28,4	56,1	0,82
Small industry and Household:								
Anthracitic	0,17	29,62	29,52	2,4	13,4	8,1	76,1	1,05
Bituminous	6,70	27,07	26,99	3,1	15,1	25,6	56,2	0,82

Source: Pinheiro *et al.* 1997.

Note 1 Gross calorific value (MJ/kg) = calorific value (MJ/kg) - (0.095 x total sulphur %)