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

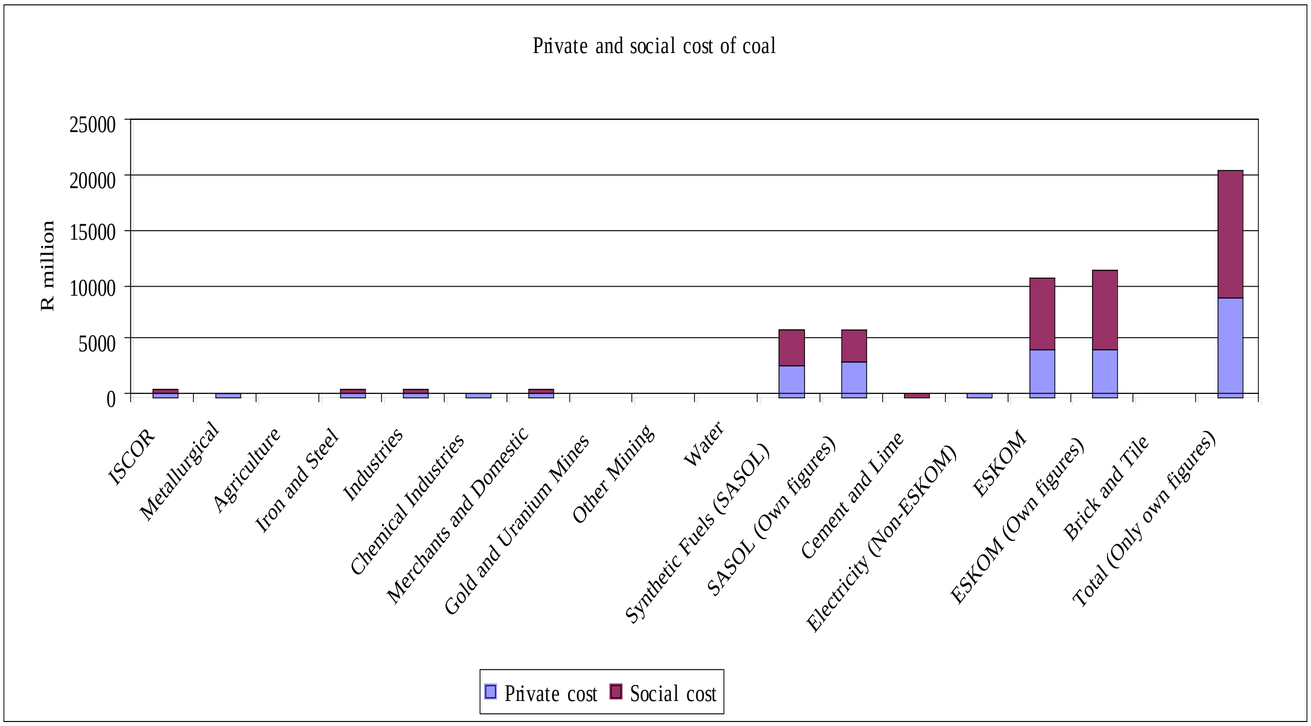
	Volume of coal purchased	Total private cost	Average private price	Social cost[b]	Social cost as % of private cost	Total private & social cost	Average private & social price	Difference: Total prvte & social price & private price
	t	R million	R/t	R million	%	R million	R/t	R/t
	a	b	c	d	d/b = e	b+d = f	f/a = 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

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).

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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 %)

The Clean Development Mechanism and Environmental Assessments[9]

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1 BACKGROUND

South Africa is currently positioning itself in the international climate change regime. Internationally, carbon has increased in economic value and the implicit total asset value of the Kyoto allocation of the atmosphere amounts to $US2 trillion (Victor 2001) of which only around US$100million was traded in the five year period 1996 – 2001. With a renegotiated Kyoto Protocol, even without the United States, the potential market for carbon is sufficiently large to warrant proper segmentation. Different developing countries would be able to benefit differently from the trading rules that have to be formalised in the near future.

In the 1997 Kyoto Protocol, three flexibility mechanisms, or Kyoto mechanisms, were created. These mechanisms are ways by which Annex I countries to the Protocol can reduce their legally binding emission reduction targets by an average 5.2% below 1990 levels in the accounting period 2008-2012. The Kyoto mechanisms have been created with a view of achieving these targets at the lowest possible costs for those countries committed to greenhouse gas reductions (Toman & Cazorla 1998). The Clean Development Mechanism (CDM), apart from Joint Implementation (JI) and International Emissions Trading (IET), is one of these Kyoto mechanisms.

The CDM is a project-based mechanism aimed at obtaining Certified Emission Reductions (CERs) at the lowest possible costs. These CERs are obtained through an investment in greenhouse gas reducing technologies or carbon sequestration projects in developing countries by developed countries or entities within developed countries.

The problem addressed in this paper is that the costs of administering CDM projects will be greatest at the outset of the project as methodologies are being developed, tested and established in practice. The design of a standardised process approach that is easy to apply and replicate will be essential to minimise transaction costs. A set of streamlined steps should be rigorously applied in establishing a CDM project. Frameworks and models are required to assist entities in their approach to a transaction (Thorne and La Rovere 1999). However, if such procedures are excessively complicated and slow, project promoters may decide not to apply for CDM funding as the resulting costs may offset the credits, and therefore potential economic benefits to the country could be lost (Synergy Programme 2000). If not supported by a well-functioning assessment process, the requirement that CDM projects ought to contribute to sustainable development is a possible source of such increased economic costs. This project attempts to bridge the gap between the need for lower transaction costs and the requirements of meeting sustainable development criteria.

[9] This project was sponsored by USAID and administered by the Joint Center for Political and Economic Studies under subcontract to Nathan Associates, Inc. Nathan Associates is the prime contractor for implementing USAID's Support for Economic Growth and Analysis (SEGA) project and is secretariat to the Forum for Economics and Environment.

2 PURPOSE AND OBJECTIVES

The purpose of this project is to find ways in which sustainable development objectives in the CDM can be met at least cost.

This project set out to achieve the following:
(1) To determine the viability of the EIA process as a framework for assessing CDM projects; and
(2) To investigate CDM as an alternative mitigation option in traditional EIA projects.

3 SUSTAINABLE DEVELOPMENT

A key question is how South Africa can achieve sustainable development on CDM projects, without raising transaction costs to such an extent that international CDM investors would rather invest in other countries. This requires some discussion on the meaning of sustainable development.

Sustainable development is probably the most used (and misused) term in the environment and development debate of today. There is confusion in the term alone due to the lack of agreement regarding exactly what is to be sustained, for whom, and by what means (Redclift 1992, Frazier 1997). Ecologists, developers, planners, economists and environmental activists often mean different things when they use the term even though there is apparent consensus. This is a reflection of disciplinary biases, distinctive paradigms and ideological disputes. The sustainable development literature does not resolve the conflict and there are numerous authors who have redefined the concept to suit their needs.

The definition that has become best known and most widely used is that of the Bruntland Commission (World Commission of Environment and Development 1987) which defines sustainable development as "*Development that meets the needs of the present without compromising that of future generations to meet their own needs*". This definition places human need in the foreground of the development debate, arguing that the viability of natural systems should be assured so as to meet human needs in the future. Rather than enter the debate, which would add to the confusion, the Bruntland definition has been adopted in this work.

4 EIA IN SOUTH AFRICA

Sustainable development is one of the guiding principles adopted under both the National Environmental Management Act (NEMA) of 1998 and the Environment Conservation Act of 1989. According to the NEMA (Government Gazette 1998), development must be socially, environmentally and economically sustainable. The 1998 EIA regulations provide one of the tools to implement the principles (DEAT 1998, Makhaye 2001). It should be noted that the NEMA is currently being revised and a draft report is expected to be released for comment in the near future (possibly in June 2002).

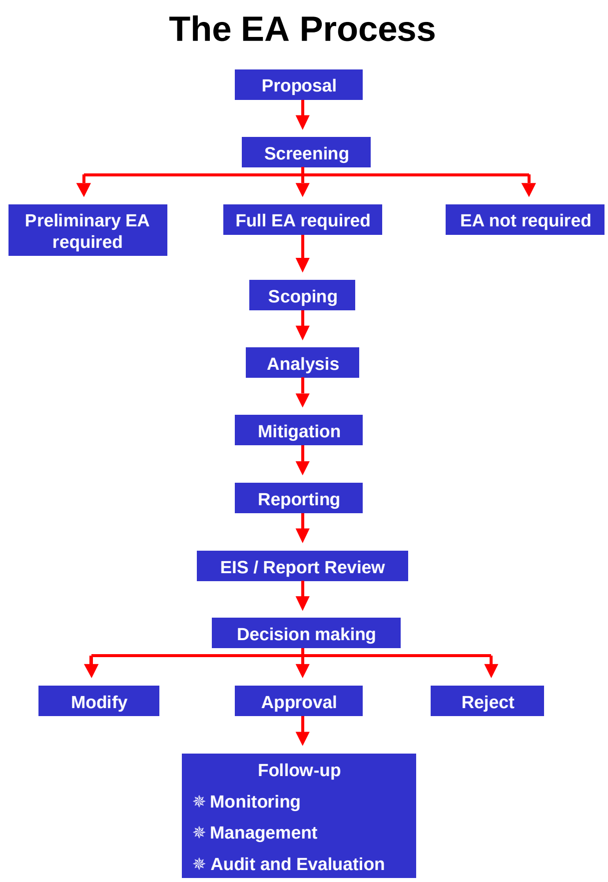
The South African experience is that EIAs do not guarantee sustainable development, although the process in itself works relatively well. The revised regulations under NEMA may specify sustainable development criteria and suggest tools to assess whether projects comply with these or not. At present, EIAs, if conducted properly to take into account the development's impact on the biophysical, social and economic environment, go some way towards ensuring sustainable development.

5 APPROACH

The approach of the project was to take the existing EIA and CDM processes and integrate the two. The reasons for doing so were twofold: (1) the EIA process is well-established in South Africa as a mechanism for assessing new developments and (2) Environmental Impact Assessment is a recognised tool for application of sustainable development criteria.

The EIA process in South Africa was undergoing revision at the time of the study so it was decided to use the United Nations Environment Programme's generic Environmental Assessment[10] (EA) process (Figure 1).

Figure 1 The generic Environmental Assessment process (after Sadler, 1996)



The EA process involves a screening stage to determine whether an EA is required or not. If an environmental assessment is required, scoping is conducted, followed by analyses of the impacts and suggesting mitigatory measures to negate adverse impacts. A report is compiled which is submitted for peer and authority review. At the decision-making stage, the development proposal can either be rejected or accepted (with or without modifications and conditions for approval). An environmental management plan would include monitoring, management and auditing.

A generic flow diagram for the CDM process is illustrated in Figure 2. Following identification of the project, the project is assessed for its carbon credits and socio-economic effects. Thereafter, financing is obtained, CERs are created and the project is registered with the authorities. Finally, continuous monitoring, verification and certification takes place.

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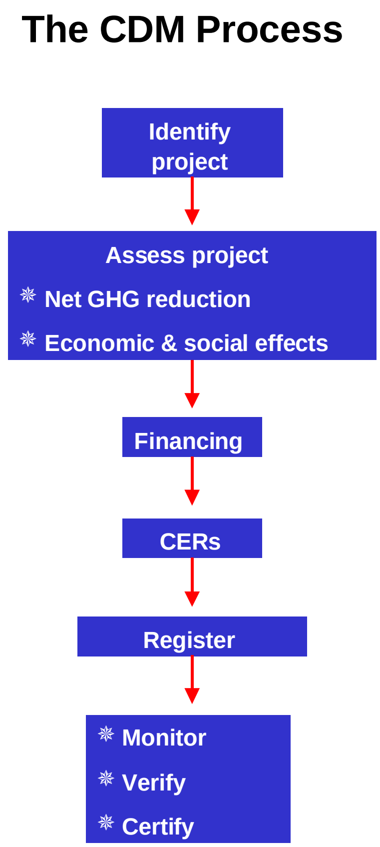
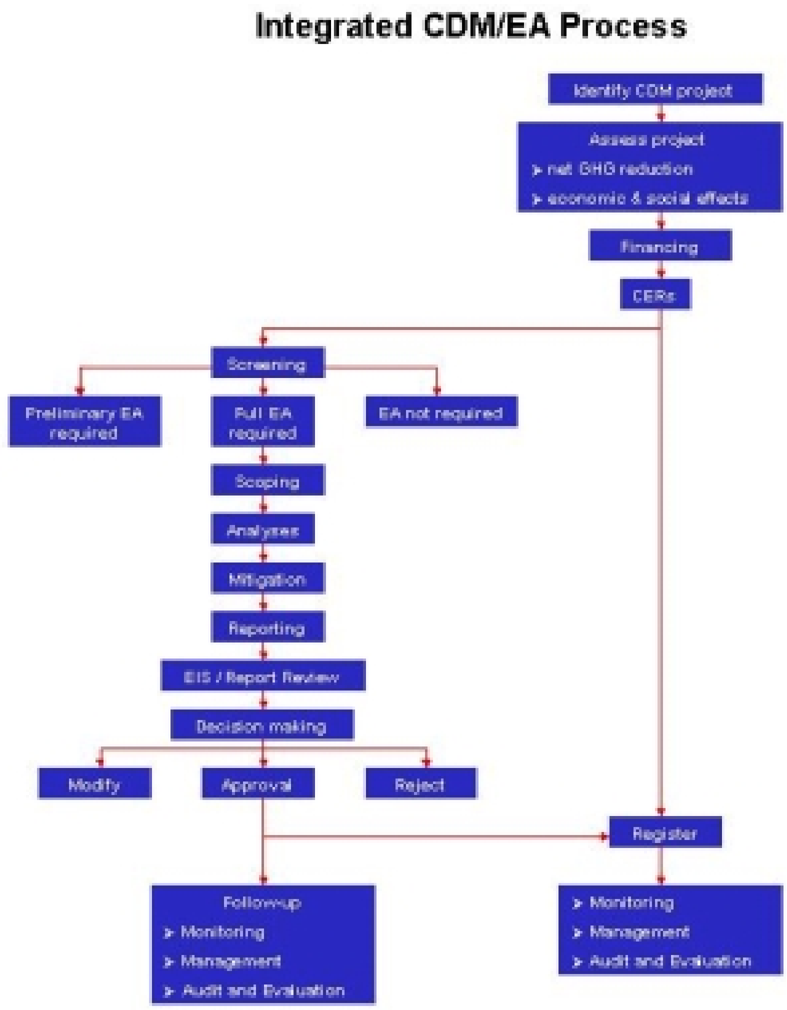
[10] The terms 'Environmental Impact Assessment' and 'Environmental Assessment' have been used interchangeably. However, some distinction is drawn between the two as 'EIA' has specific reference to South Africa, while 'EA' is a

Figure 2 The generic CDM process



There are still some reservations on whether the EIA process specifically guarantees sustainable development. However, as government is still using the EIA process as a key tool to achieve sustainable development outcomes, a first step would be to conceptually integrate the CDM and EIA processes. Such an integrated process is illustrated in Figure 3.

Figure 3 The integrated EA/CDM process



Conceptually the integration of the EIA and CDM processes is relatively straightforward. It is suggested that the CDM project is assessed for its economic viability and carbon reduction potential before a full EIA is carried out. However, whether a CDM can be registered finally with the authorities is dependent on the EIA process. In this way, the CDM project is measured for sustainable development through existing processes that work well and minimise transaction costs.

It should be borne in mind that for full integration to occur, questions relating to the CDM need to be asked at various stages of the assessment process. A CDM specialist study, for example, could be commissioned to deal with CDM aspects of the project, taking into account impacts on the biophysical, economic and social environments.

Although the integrated process has been depicted as a sequential process, there should be dove-tailing between the various steps.

6 FACTS ABOUT THE CDM

Before the guidelines are presented, it would be beneficial to provide a broader context of the international climate and investment regimes. The following issues provide the context for assessing CDM projects:

- The CDM operates within an uncertain Kyoto Protocol and finalisation of trading and investment rules. Uncertainty still dominates many aspects of this mechanism.

- The AIJ (Activities Implemented Jointly) phase poses some interesting learning points for CDM, specifically related to the cost of transacting and the existing links between institutions and development cooperation, or what is called ‘neighbourhood trading’. Most successful AIJ projects have low transaction costs and cluster around existing trade and development patterns.

- CDM operates in a context of a broader investment climate. South Africa attracts very little foreign direct investment (FDI). The reasons for this vary, but the important point is that investors will not start investing in South Africa just because emissions reduction credits can be achieved. South Africa competes with many other nations and projects for such opportunities.

- CDM can be distinguished from other developments, through its focus on reducing carbon emissions and to meet the objective of sustainable development. Sovereign nations can set their own principles for sustainable development, but this needs to be balanced with the costs of requiring such principles in the assessment of CDM projects.

- Based on this information it is clear that a need exists to use a simple assessment process for CDM projects, without compromising on the objectives of sustainable development. Investors need to be able to have a ‘one-stop’ service where potential CDM projects are assessed, registered, certified and monitored. This creates investment certainty, a prerequisite for any successful investment programme.

- The current EIA process, although in revision, provides a useful platform on which CDM assessment can be carried out. Several changes need to be implemented though, to take account of the special requirements of CDM projects, specifically the reduction of carbon emissions and meeting the objectives of sustainable development.

- Therefore, an integrated EIA-CDM process is suggested as illustrated in Figure 3.

7 CASE STUDIES

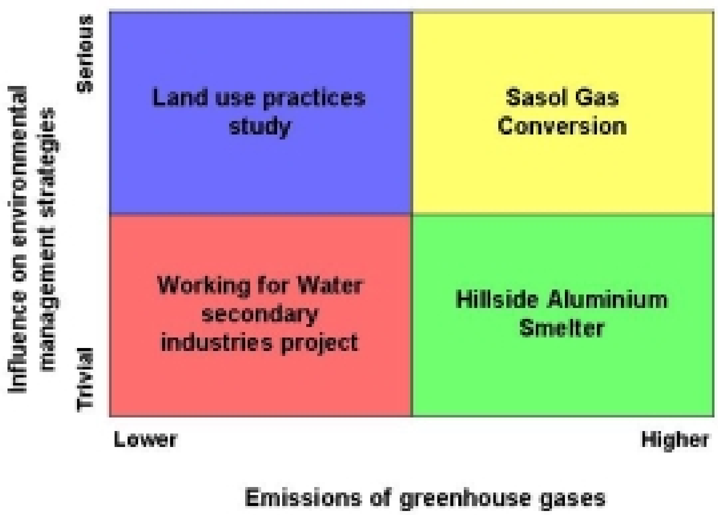
Case studies were used in this project to better illustrate the impact of the CDM on emissions reduction and the achievement of sustainable development objectives. A broad set of case studies was selected to provide the widest possible coverage of possible CDM projects as possible. Figure 4 illustrates the approach to the case study selection. Axes were chosen on (i) the impact that carbon reduction strategies would have on environmental management strategies, i.e. is it considered to be either a great opportunity or a threat?, and (ii) the amount of greenhouse gases emitted.

The Working for Water (WfW) secondary industries project is already ongoing and is focused on issues such as water, biodiversity and job creation. When the WfW programme commenced, there was some concern that the removal of biomass would have a negative effect on the global climate. Since the alien infestations grew by removal of CO_2 from the atmosphere in the first place, their decay or combustion has a relatively minor net effect with respect to the atmospheric CO_2 concentration.
The Hillside aluminium smelter emits large quantities of greenhouse gases, but decision-making has focused on local issues. This case study was used to assess the potential gains of including CDM as a mitigation option in the EA.

The land use practices study, although it has a small impact on the overall greenhouse gas balance, could have large impacts on decision-making, In the context of the Kyoto protocol, net changes in greenhouse gas emissions resulting from changes in land management practices specifically undertaken for this purpose may become eligible for support under the CDM. To become eligible, they would need to demonstrate not only a net greenhouse gas reduction, but also that the land use practices were consistent with sustainable development.

In the case of the Sasol Gas Conversion project, large amounts of greenhouse gases are mitigated through the use of natural gas in the place of coal as a feedstock. If these are eligible for carbon reduction credits, there are potential huge gains if the issue of additionality is resolved. An unknown factor is the impact of methane emissions. In principle, methane emissions from the actual syngas production step are small. However, methane and non-methane hydrocarbon emissions can be significant from poorly-operated or maintained gas well fields and pipelines. The assessment would need to take this into account.

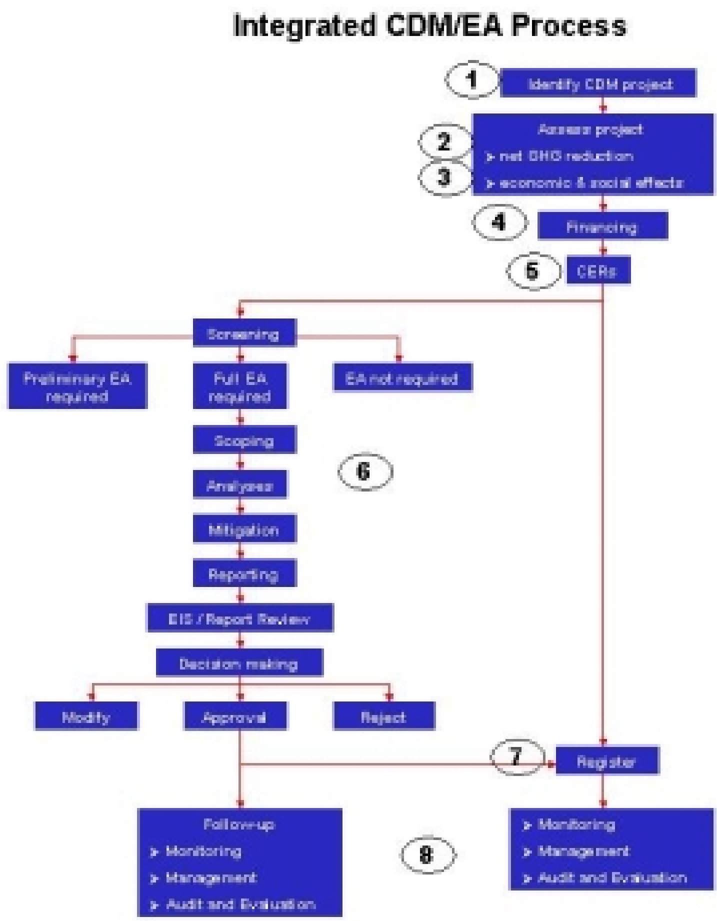
Figure 4 Matrix used for selection of case studies



8 PROCESS FOR ASSESSMENT OF CDM PROJECT

Using the integrated assessment process (Figure 5**)** it is suggested that the following steps be undertaken:

Figure 5 Numbered steps in integrated process for use in conjunction with the guidelines



1. Identification of the CDM project
    a. Determine whether or not the project has carbon reduction potential.
    b. Determine whether the project is eligible for the CDM.
        i. Net changes in land management are eligible for CDM, but rules are not clear at this stage.
        ii. Potential for CDM support for expansion of aluminium smelters is limited due to minor process energy efficiency improvements.
        iii. Early indications are that secondary industries based on biomass will not be eligible for CDM, mainly because of relatively high methane emissions.
        iv. Natural gas projects are likely to be viable for CDM.
    c. Source funding for feasibility studies

2. Assess the project's net greenhouse gas emissions reduction
    a. For calculation of greenhouse gas baseline emissions follow IPCC (1996) recommendations, unless otherwise specified.

   b. No specific standardised methodology for baseline estimation has been agreed upon yet. Baseline and intervention assumptions need to be stated clearly.
   c. It is not clear at this stage whether both local and remote (or off-site) greenhouse gases need to be included in the baseline of an operation. This could have serious impacts on activities relying on high greenhouse gas emitting activities upstream (such as cheap electricity from coal burning).
   d. The concept of additionality would be important when calculating net GHG reductions. This would especially be the case with projects that are justified on economic grounds, such as the Sasol natural gas conversion project.

3. Financial and social assessment
   a. Determine whether the project is feasible on financial and social grounds. This step could be carried out during the impact assessment phase of the EA.

4. Obtain financing for project

5. Calculate certified emissions reductions (CERs)

6. Conduct EIA
   a. The following the CDM projects would require an EIA under current legislation:
      i. Land management practices: Afforestation and possibly manure management (if on a large scale)
      ii. Natural gas substitution
   b. The following case studies would probably only need scoping:
      i. Activities with overwhelmingly positive non-greenhouse gas reduction benefits (reduced tillage reduces erosion, non-burning of sugar cane reduces air pollution, reduction in national herd reduces range degradation)
      ii. Energy efficiency improvements, depending on local and remote impacts.
   c. Follow the procedure laid out in the guideline document for EIA Regulations (DEAT 1998), but the release of a more comprehensive environmental assessment by DEAT can be expected soon (possibly June 2002).
   d. Sustainable development criteria for CDM projects have not been included in the EIA process yet. These could be included in comprehensive revision of EA in the country.

7. If EIA is approved, register project
   a. Certify CERs
   b. Register with authorities (UNFCCC and /or national authorities)

8. Draw up Environmental Management Plan (EMP) to monitor, manage, audit
   a. Include all aspects of an EIA, but in addition include CERs.

9 PROCESS FOR USING CDM PROJECT AS MITIAGATORY OPTION FOR GREENHOUSE GAS IMPACTS

1. Conduct EIA (Step 6 in Figure 5)
   a. Follow procedure laid out in Guideline document for EIA Regulations (DEAT 1998)
   b. Include greenhouse gas impact specialist study in assessment
   c. Assess feasibility of CDM project as a mitigatory option for post-development levels of greenhouse gas emissions:
      i. For expansion on aluminium smelter only limited efficiency improvements can be achieved. A CDM project will most probably not be feasible

ii. For the natural gas substitution project, CDM benefits can be achieved (under condition of additionality rules) and no separate CDM project needs to be defined for mitigation of GHGs.
iii. For secondary industries based on biomass, possibilities for reducing methane might exist, but have not been reviewed.
iv. For land management practices, CDM benefits can also be achieved, and no separate CDM project needs to be defined for the mitigation of GHGs.

2. Apply process for assessment of CDM project (Steps 7 and 8 in Figure 5)
   a. Follow guidelines set out for 'assessment of CDM project' (i.e. register project, certify and validate CERs, monitor, manage and audit impacts, including GHGs).

10 LEARNING POINTS

Following from the case studies the following learning points apply:

i. A strategic environmental assessment would be needed to analyse a large number of technical CDM options and trade-offs between various costs and benefits. It would also have to address the issues of on-site (local) and off-site (remote) impacts. An example of a remote impact is the use of electricity produced elsewhere from, for example, coal burning. EIAs rarely take into account off-site or remote impacts.
ii. Where processes are technologically advanced, such as in the case of the expansion for the aluminium smelter, little GHG reductions can further be achieved to justify an on-site CDM project.
iii. Whether a greenhouse gas specialist study would need to be conducted is ultimately, under the current legislation, dependent on an 'issues driven' EIA process. When the costs of GHG impacts and the benefits of reducing GHGs, through mechanisms such as the CDM become more generally recognised, greenhouse gas studies would become more commonplace in environmental assessment processes.

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General Equilibrium Analysis of the Effects of a Consumption Tax of CO_2 Emissions

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1 INTRODUCTION

The concept of general equilibrium modeling has developed over the past two centuries. Adam Smith's description of the behaviour of capitalists, motivated by considerations of profitability in the selection of economic activities, and John Stuart Mill's treatment of international trade and agent's responses to changes in taxes and import duties, can be viewed as the source of inspiration for this type of modeling framework. However, work by Leon Walras in 1854 allowed general equilibrium modelling to reach a mature form when he provided a general description of the functioning of a complex economic system based on the interaction of a number of interdependent economic units. Walras' work was expanded, and solutions to some of the caveats in his formulations of a general equilibrium, was provided by the increase in activity in mathematical economics that took place in the 1940's and 1950's by mathematical economists such as Arrow (1954), Debreu (1954) and MacKenzie. The most significant contribution by the mathematical economists were in the mathematical confirmation of the consistency of the general equilibrium model (1954) [Scarf et al (1984, ix)].

In their text describing their General Equilibrium model for the US economy, Ballard et al (1985) introduce the usefulness of this type of model by stating: "*Many questions of economic policy can be analysed within a partial equilibrium framework. When policy changes being considered are relatively small, it may be appropriate to neglect general equilibrium interactions among many different markets. However, when large policy changes are considered, partial equilibrium analysis becomes painfully inadequate. In recognition of this fact, a vast increase has occurred in the past twenty years in the number of economists who uses general equilibrium models*."

Scarf and Shoven (1984) expands on this description by stating that one of the virtues of the general equilibrium model is its ability to trace the consequences of large changes in a particular sector throughout the entire economy. A general equilibrium model is therefore an expansion of input-output analysis in that it permits a more flexible treatment of the consumer side of the economy and is less rigid in the requirements that it places on the productivity side. They confirm the statement of Ballard et al (1985): "*The consequences of a change in economic policy are frequently analysed by assuming the changes to be small and using local linear approximations based on estimates of the relevant elasticities. If the sectors are small, diagrammatic techniques or explicit analytical results may also be available as in the two-sector models so frequently used in international trade theory. But if the model is disaggregated, and if changes – possibly more than one – are large, there is no recourse other than the construction and explicit solution of a numerical general equilibrium model.*" (Scarf et al (1984), xi).

It is therefore hardly surprising that General Equilibrium Models have been used to analyse policy issues such as:

1. Changes in tariffs, exchange rates and other trade policies [Jones, Whalley and Wiggle (1985), Harris and Cox (1984), Dixon Parmenter and Rimmer (1985)].
2. Changes in tax policy [Fullerton, King, Shoven and Whalley (1981), Piggot and Whalley (1985b)].
3. Changes in energy prices or environmental and energy policies [Hudson and Jorgenson (1974), Borges and Golder (1984), Vincent, Dixon, Parmentor and Sams (1979, 1980)]

4. Changes in the development process [Adelman and Robinson (1982), Dervis, de Melo and Robinson (1982).

1.1 Describing a general equilibrium model

A general equilibrium model is an economic model, based on the underlying economic theory of general equilibrium. According to Mansfield (1991), a state of general equilibrium is a state in which the following conditions hold:

1. Every consumer chooses a consumer basket subject to a budget constraint, which is determined by the prices of inputs and the prices of products.
2. Every consumer supplies whatever amount of inputs he or she chooses, given the input of product prices that prevail.
3. Every firm maximises profits subject to a budget constraint imposed by the available technology, the demand for its product, and the supply of inputs; however, in the long run economic profits are zero.
4. *The quantity demanded equals the quantity supplied at the prevailing prices in all product and input markets*.

Shoven and Whalley (1984) describe a general equilibrium as a state in which *all markets clear*. This is supported by Varian's (1991) comments that, in a general equilibrium, all prices are variable, and equilibrium requires that *all markets clear*. As stated above, the existence of such a state in the economy was first proven by Leon Walras.

From Walras' work it has been shown that:

1. ***An equilibrium set of prices will only exist if there is no good for which there is positive excess demand (Walrasian equilibrium)***
2. For any set of equilibrium prices the value of the excess demand is identically zero (Walras's law)
3. If demand equals supply in k-1 markets, and the price of the good in the k^{th} market is positive, then demand must equal supply in the k^{th} market.
4. If a set of prices result in Walrasian equilibrium and some goods are in excess supply at this equilibrium it must be a free good.

From the above it seems as if a feature of a general equilibrium model is that a set of prices, and levels of production and consumption exists in each industry and household, such that market demand equals supply for all commodities.

A very descriptive summary of what a general equilibrium model entails are given by Scarf et al (1984). According to them, the fundamental theme of a general equilibrium model lies within the heart of economic theory. The production side of the economy, engaged in the transformation of certain commodities into other commodities, is distinguished from the consumption side, whose goals are the acquisition and eventual consumption of goods and services. Households own stocks of commodities, which may be consumed directly, maintained as inventories for eventual use, or offered as factors of production, in a physical form, or by means of a variety of financial instruments. Consumer's income, or wealth, is determined by evaluating his stock of commodities in terms of those prices at which the commodities can be sold. Income and knowledge of relative prices permit the consumer to express his demands for goods and services and his offerings of labor and other stocks that are made available for the productive side of the economy. The decisions of the production and consumption sides of the economy need not be consistent with each other if they are based on an arbitrary set of prices. If the prices of a desired commodity are too low, consumers may be motivated to demand large quantities of this commodity, and producers may be averse to supplying that commodity whose sales generate insufficient revenue to cover the costs of manufacturing the commodity. Equilibrium prices are therefore those prices that equate demand and supply in all markets, and once they are known, economic decisions are based on them. (Scarf et al (1984).

Given the above description of a general equilibrium model, it is necessary to briefly define an applied general equilibrium model:

An applied general equilibrium model is nothing more than a general equilibrium model that can be used to provide quantitative analysis of economic policy problems. An AGE therefore need, apart from the theoretical structure, provided by a general equilibrium model, also some data about the economy of interest. Once the general equilibrium model and data has been integrated, an actual solution method needs to be determined in order to solve for the equilibrium prices and decision variables in the equilibrium system. [Dixon et al, 1991].

The development of an applied general equilibrium model, typically includes the following steps:

1. Development of a theoretical structure consisting of:
   i. Equations representing household and other final demands for commodities.
   ii. Equations for intermediate and primary factor inputs.
   iii. Pricing equations relating commodity prices to costs.
   iv. Market clearing equations for primary factor and commodities.

Use of input output data to provide estimates for the relevant cost and sales shares.

1.2 Application of a general equilibrium model in the study

We examine the effect of a tax on goods, which are produced through high levels of CO_2 emissions. The motivation behind this paper is derived from research conducted in the field of environmental tax policies. Although our application is simplified in that our current model does not include the use of energy sources in the production process, we examine the effects of such a tax on a number of social and economic variables in the South African economy. This tax will be redistributed towards the economy in the form of lower marginal income tax rates on the six income groups that we distinguish within our model. Environmental groups argue that a tax system which uses revenues from a CO_2 tax, to lower existing taxes, e.g. by lowering income taxes, will not only enhance environmental quality, but also decrease the excess burden imposed on the economy by the tax system. This enhancement in both the environment, as well as the economy, is known as the double dividend of an environmental tax policy.

2. THE DOUBLE-DIVIDEND HYPOTHESIS

Felder and Nieuwkoop (1996) mentioned three distinct definitions of the concept of a double dividend:

"Weak form": By using revenues from the environmental tax to finance reductions in marginal tax rates of an existing distortionary tax, one achieves cost savings relative to the case where the tax revenues are returned to tax-payers in lump-sum fashion.

"Intermediate form": It is possible to find a distortionary tax such that the revenue-neutral substitution for this tax involves a zero or negative gross cost.

"Strong form": The revenue-neutral substitution of the environment tax for typical or representative distortionary taxes involves a zero or negative gross cost.

The weak form of the double dividend hypothesis has proved to be uncontroversial in the literature, and has a straightforward welfare implication for CO_2 tax proposals. That is, by recycling the revenue lump sum rather than cutting existing distortionary tax, the government misses the opportunity to reduce the gross costs of its environmental policy. The conditions for the other forms of the double dividend are stronger and therefore more controversial. The stronger forms only differ to the extent of their level of generalization: the intermediate form claims that a double dividend will occur only when a particular distortionary tax is reduced, the strong form postulates that a double dividend will occur by the reduction of a typical can be separated into the cost of the environmental tax and the cost of an equal-revenue change in the distortionary tax. Both the intermediate and the strong forms claim that the first cost is always smaller than the second.

The theoretical as well as the empirical literature cast doubt on the validity of the double dividend hypothesis. One such finding by Bovenberg and de Mooij (1994) is that revenue-neutral environmental taxes compound the distortions of labor taxes and, as a result, tend to involve positive gross costs. The intuition behind these results is that the tax base erodes as taxation is shifted from the broader based labor income tax to selective environmental taxes. This reduces the tax base by inducing households to substitute “cleaner” commodities, and if the government wishes to maintain unchanged tax revenues, it will therefore be unable to cut labor taxes so much as to compensate workers for the erosion of their after-tax real wage stemming from higher environmental taxes. As a result, employment decreases rather than rises as a consequence of the environmental tax reform (Felder et al. 1997).

3. APPLIED GENERAL EQUILIBRIUM MODELLING – A SIMPLE EXAMPLE

A short example, of a General Equilibrium Model illustrates the usefulness of this type of models in policy analysis. We make use of an example put forward by Shoven and Whalley (1981).

Consider a model with:

- Two final goods.
- Two factors of production.
- Two classes of consumers, a rich class and a poor class.
- Rich consumers own all the capital, while poor consumers own all the labour.
- Production takes place according to constant returns to scale Constant Elasticity of Substitution production function.
- Each consumer class has commodity demand functions that is generated by maximising a Constant Elasticity of Substitution utility function, subject to a budget constraint.

The production function is given by:

$$Q_i = \phi_i [\delta_i L_i^{\frac{\sigma_i - 1}{\sigma_i}} + (1-\delta_i) K_i^{\frac{\sigma_i - 1}{\sigma_i}}]^{\frac{\sigma_i}{\sigma_i - 1}}, i = 1,2$$

Q_i= Output of the ith industry.
Φ_i= Scale Parameter
δ_i= Distribution parameter
K_i = Capital inputs
L_i = Labor inputs
σ_i Elasticity of factor substitution
The factor demand functions, which are derived from the above production function, are given by:

$$L_i = \phi_i^{-1} Q_i [\delta_i + (1-\delta_i)[\frac{\delta_i P_k}{(1-\delta_i)P_L}]^{1-\sigma_i}]^{\frac{\sigma_i}{1-\sigma_i}}$$

$$K_i = \phi_i^{-1} Q_i [(1-\delta_i) + \delta_i [\frac{(1-\delta_i)P_L}{(1-\delta_i)P_K}]^{1-\sigma_i}]^{\frac{\sigma_i}{1-\sigma_i}}$$

In order to derive the demand functions for the two products, the CES utility function is given by:

$$U^c = [\quad \alpha_i^{c\frac{1}{\sigma}} \leftrightarrow X_i^{c\frac{\sigma_c - 1}{\sigma_c}} \quad]^{\frac{\sigma_c}{\sigma_c - 1}}$$

X_i^c = Quantity of good I demanded by consumer c.
α_i^c = Share parameter.
σ_c = Elasticity of substitution in consumer c^s CES utility function.

By maximising the utility function subject to the consumer's budget constraint, the demand functions are derived:

$$X_i^c = \frac{\sigma_i^c I_c}{P_{ii}^{\sigma_c}(\alpha_i^c P_1^{(1-\sigma_c)} + \alpha_2^c P_2^{1-\sigma_c})}$$

The derived factor and product demand functions indicate that there are ten parameters that have to be estimated in this model. For the production functions these are: ϕi, δ_i, σ_i for each of the two production functions and α_1^1, α_1^2,σ_1,σ_2 for the utility functions.

The solution of the model will then be characterised by 12 variables:

P_1, P_2, P_L, P_K, X_1^1, X_2^1, X_2^1, X_2^2, K_1, K_2, L_1, L_2.

Before the model can be solved, the equilibrium conditions must be specified. These state that market demand equals market supply for all inputs and outputs and that profits are zero in each industry. These conditions can be described by the following equations:

- Demand equals supply for all factors:
  $K_1(P_l,P_k:Q) + K_2(P_l,P_k:Q) = K$
  $L_1(P_l,P_k:Q) + L_2(P_l,P_k:Q) = L$

- Demand equals supply for all goods:
  $X_1^1(P_1,P_2,P_l,P_k) + X_1^2 (P_1,P_2,P_l,P_k) = Q_1$
  $X_2^1(P_1,P_2,P_l,P_k) + X_2^2 (P_1,P_2,P_l,P_k) = Q_2$

- Zero profit conditions hold in both industries:
  $P_kK_1(P_l,P_k,Q) + P_LL_1(P_l,P_k,Q) = P_1Q_1$
  $P_kK_2(P_2,P_k,Q) + P_LL_2(P_2,P_k,Q) = P_2Q_2$

With the model specified, the parameters of the demand and production functions must be determined and the endowments specified. The estimation of the parameters in a general equilibrium framework is discussed in subsequent sections. For the moment, assume the following parameters for the model.

Production Parameters			
	ϕ	δ	σ
Manufacturing	1.5	0.6	2.0
Non Manufacturing	2.0	0.7	0.5

Demand Parameters					
Rich Consumers			**Poor Consumers**		
α_1^c	α_2^c	σ^c	α_1^c	α_2^c	σ^c
0.5	0.5	1.5	0.3	0.7	0.75

Endowments		
	K	**L**
Rich Households	25	0
Poor Households	0	60

By making use of the Scarf algorithm to find a solution for the non-linear system of equations, the solution in the table below was established.

Equilibrium prices	
Manufacturing output	1.399
Non-manufacturing Output	1.093
Capital	1.373
Labour	1.00

Production				
	Quantity	**Revenue**	**Capital**	**Capital Cost**
Manufacturing	24.942	34.898	6.212	8.532
Nonmanufacturing	54.378	59.439	18.78	25.805
Total		94.337	25	34.337
	Labour	**Labour Cost**	**Total Cost**	**Cost per unit output**
Manufacturing	26.366	26.366	34.898	1.399
Nonmanufacturing	33.634	33.634	59.439	1.093
Total	60	60	94.337	

Demands			
	Manufacturing	**Non-Manufacturing**	**Expenditure**
Rich Household	11.514	16.674	34.337
Poor Household	13.428	37.704	60.00
Total	24.942	54.378	94.337
	Labour Income	**Capital Income**	**Total Income**
Rich Household	0	34.337	34.337
Poor Household	60	0	60
Total	60	34.337	94.337

Shoven and Whalley then illustrates how a general equilibrium solution can be used to analyse policy changes by adding a tax of 50 percent on each unit of capital income generated in the manufacturing sector. They assume that rich households receive 40 percent of the tax revenue, while poor households receive 60 percent. According to the authors a naïve method of calculating the tax revenues will be by taking the initial solution. In a no-tax regime, the units of capital used are 6.212 and the price is 1.373, which give total tax revenue of 4.265. However, general equilibrium analysis indicates that when allowance is made for all the general equilibrium responses, the new revenue is only 2.278. This can be attributed towards the fact that the tax leads to less capital-intensive methods to be used in the manufacturing sector. Less manufacturing products and more non-manufacturing products will be used. It will further give raise in expenditures by poor households and a fall in expenditure by rich households.

Apart from allowing analysts to determine the full general equilibrium impact of policy changes. Applied general equilibrium models are also frequently used to address the problem of whether any particular policy on a comparison of existing equilibrium and a counterfactual equilibrium, computed with modified policies. The measures widely used to determine whether any welfare effects have indeed taken place is the calculation of equivalent variation (EV) and compensating variation (CV):

$$CV = \left(\frac{U^{n} - U^{o}}{U^{N}}\right) \times I^{N}$$

$$EV = \left(\frac{U^{N} - U^{I}}{U^{o}}\right) \times I^{O}$$

3.1 An Overview of the AGE applied to this Policy Analysis

The above example made it clear that AGE models can be fruitful, and flexible vehicles for practical policy analysis. The model that is utilised in this policy evaluation is based on the ORANI G model of the Australian economy. The ORANI G model is allows for comparative, static analysis and was first developed in the late 1970’s. It served as a launching pad for the development of models for South Africa, Vietnam, South Korea, Thailand, Philippines, Pakistan, Denmark and China. The South African version of ORANI G is utilised in this policy simulation.

The model has a theoretical structure that is typical of a static AGE model. It consists of equations describing for some period:

1. Producer’s demands for produced inputs and primary factors.
2. Producer’s supplies of commodities.
3. Demands for inputs to capital formation.
4. Household demands.
5. Export demands.
6. Government demands.
7. The relationship of basic values to production costs and purchasers prices.
8. Market clearing conditions for commodities and primary factors.
9. Numerous macroeconomic variables and price indices.

These equations describe a South African economy that distinguishes between 36 industries and commodities (34 non-margin commodities, and 2 margin commodities), 2 sources of the commodities, 13 occupations and six income groups, as described in the table below: As illustrated in the example above, the demand and supply equations for private sector agents are derived from the solutions to optimisation (or minimisation) problems. Agents are assumed to be price takers, with producers operating in competitive markets.

Table 1: Distinction between industries, commodities, labour and income groupings.

Industries	Commodities	Labour	Income Groups
1. Agriculture	1. Agriculture	1. Professionals	1.
2. Gold Mining	2. Gold Mining	2. Semi Professionals	2.
3. Other Mining	3. Other Mining	3. Technicians	3.
4. Food	4. Food	4. Managerial	4.
5. Beverages	5. Beverages	5. Clerical workers	5.
6. Tobacco	6. Tobacco	6. Sales persons	6.
7. Textile	7. Textile	7. Transport workers	
8. Clothing	8. Clothing	8. Service occupations	
9. Leather	9. Leather	9. Farming	
10. Footwear	10. Footwear	10. Artisan apprentice	
11. Wood	11. Wood	11. Production foreman	
12. Furniture	12. Furniture	12. Labourer	
13. Paper	13. Paper	13. Unspecified	
14. Printing	14. Printing		
15. Chemical	15. Chemical		
16. Rubber	16. Rubber		
17. Plastic	17. Plastic		
18. Non Metal	18. Non Metal		
19. Basic Metal	19. Basic Metal		
20. Fabric Metal	20. Fabric Metal		
21. Machinery	21. Machinery		
22. Electric Machinery	22. Electric Machinery		
23. Transport Equipment	23. Transport Equipment		
24. Other Manufacturing	24. Other Manufacturing		
25. Electricity	25. Electricity		
26. Construction	26. Construction		
27. Civil Engineering	27. Civil Engineering		
28. Trade	28. Trade		
29. Accommodation	29. Accommodation		
30. Transport	30. Transport		
31. Communication	31. Communication		
32. Finance	32. Finance		
33. Community Services	33. Community Services		
34. Government Industries.	34. Government Industries.		
35. Servants	35. Servants		
36. Unclassified	36. Unclassified		

The data on the model is captured, as described below, within an input-output table of the South African economy (2000) and a file containing the behavioural parameters and miscellaneous variables needed to construct the Applied General Equilibrium Model.

3.2 Data requirements for a Computable General Equilibrium model

According to Dixon et al (1992), the prototype for modern applied general equilibrium models is Leontief's input-output model.

An input-output model emphasises interdependencies between different industries and households, which arise from:

1. Their role as each other's customers.
2. The purchase of material inputs by one industry from others, or of labour and capital inputs from households.
3. The purchase of consumer goods by households from industries.

The primary data input required for Applied General Equilibrium modelling is therefore an input-output table for the South African economy. Further, an Applied General Equilibrium Model include a range of interdependencies, which is wider than those arising directly from flows between agents in the economy (as illustrated in the example of section 1, and in the following sections), information on the behavioural parameters of the economy is also needed. While input-output tables record the commodity flows, which take place between the components of the economy, behavioural parameters need to be specified to summarise how agents respond to changes in activity variables and prices. Apart from describing commodity flows, the input output table can further be used to derive some of the behavioural parameters needed for the model. The process of deriving the parameters from the input output tables is extensively described in Dixon, Parmentor, Powell and Wilcoxen (1992).

Given the above, the data input for our model is organised in two separate sets of files. The first set contains the input-output data from a 2000 input-output tables. This input output database also provides the basis for computing: cost, revenue and sales shares. A second data file therefore stores the elasticity parameters, the values of the indexing parameters and the base-period values for various miscellaneous coefficients.

The following section briefly summarise the methodology in capturing the interdependencies and behavioural characteristics of the agents in the South African economy.

3.3 Producer behaviour

Within the model each industry are allowed to produce several commodities. Each industry use, as inputs, domestic as well as, imported commodities, labour, land and capital. As mentioned, distinction is made between 13 different types of labour. The production side is kept manageable by a series of seperability assumptions.

The total production function has as inputs;

1. A primary factor composite.
2. Commodity composites.
3. Other costs

These factors are combined by a Leontief technology to produce output. The commodity composites are produced through a CES technology, which combines a domestic and imported good. The factor composite is also produced by a CES technology, consisting of labour, capital and land as inputs. This technology further incorporates factor saving technology. Finally, the labour composite is also represented by a CES technology, which combines each of the different labour groups.

The attractive characteristic of the CES determination of inputs into production is the fact that relative prices determine the quantities used. For example, a rise in the price of labour relative to total effective cost of factor inputs will result in a substitution of labour for a cheaper factor of production. It must further be noted that the final production function (Leontief production technology), which combines the three factors of production into a final output, is also a CES production function with an elasticity of substitution equal to zero.

To close the production structure of the model, the zero profit condition in production is defined by setting output prices equal to average costs.

3.4 Demand for investment goods

Within the model, capital is produced with inputs of domestically produced, and imported commodities. The structure of investment demand is the same as that of the demand for intermediate goods towards production. The combination of imported and domestic goods are governed by a CES function and once the composite commodity is determined, it is combined within a Leontief function to produce capital goods for all the industries included within the model.

As with the production of intermediate goods, the zero profits condition of the investment structure of the model is stated by including an equation that specifies that the price of each unit of capital is equal to the average cost of producing the unit of capital.

3.5 Household behaviour

The structure of household demand is nearly identical to that of investment demand, however, composite commodities are aggregated by a Klein-Rubin, rather than a Leontief function. This specification results in a Linear Expenditure System in which the expenditure on each good is a linear function of prices and expenditure. The model further distinguishes between subsistence expenditures - which are commodities purchased, regardless of prices - and luxury expenditures, which is the remainder of the expenditure after the subsistence expenditure has been subtracted from total expenditure. The composite commodity is produced with a CES technology; which combined domestic and imported goods.

3.6 Export demand

The demand for exports is determined by a downward – sloping foreign demand schedule. Export volumes are declining functions of foreign currency prices. The export demand function further allows for horizontal (quantity) and vertical (price) shifts in the demand schedules.

3.7 Government demand

The model determines government consumption exogenously. However, government consumption can be determined endogenously by allowing it to change relative to household demand.

3.8 Demand for margins

Demand for margin commodities move proportional to the commodity flows with which the margins are associated.

3.9 Purchasers prices

Purchaser’s prices, for each of the five user groups (producers, investors, households, exports and the government), are the sum of the basic values of the commodities, sales taxes and margins. Sales taxes are ad-valorem taxes on basic prices.

3.10 Market clearing conditions

Apart from the market clearing equations already stated the market clearing equations for domestic commodities are also added, i.e. demand equals supply for non-margin commodities and for margin commodities.

Before moving towards taxes, it is worth noting that the model allows users the option of setting aggregate employment exogenously with market clearing wages determined endogenously, or wage rates can be set exogenously, which allows employment demand to be determined endogenously. As South Africa’s wage-fixing mechanism is determined by external negotiation, the wage rate is usually set endogenously.

3.11 The treatment of indirect taxes in the model

The model allows for flexibility in the treatment of taxes, by including equations, which implement the tax regime to be simulated. These equations treat sales taxes as ad-valorem taxes on basic values (prices). The equations allow the changes in the relevant tax rate to be commodity specific or user specific. Sales tax equations are set for producers, investors, households and the government. We incorporate the tax policy in this model by increasing the general sales tax on those commodities produced within a high pollution industry. The model aggregates each of the indirect taxes into revenue collected.

4. SOLVING THE MODEL

Early applied general equilibrium models were solved by using either the Scarf algorithm, or the Johansen procedure (Shoven and Whalley, 1984). As work on applied models developed, it has become apparent, however, that a Newton-type method or other local linearisation techniques can also be used. Another line of research has developed from Johansen's work. These solution techniques use a linearised equilibrium system to solve for an approximate equilibrium. This procedure has further been refined by Dixon, Parmentor, Sutton and Vincent (1982), who use a multi-step procedure so that approximation errors are eliminated. In the model applied in this paper, we make use of the Johansen procedure in solving the model and refer to Dixon et al (1982) for some of the advantages of this procedure:

According to Dixon et al (1982), the main advantages of the Johansen approach is its flexibility. Flexibility is gained in terms of model size, model specification and model application.

4.1 Model size

Model size can be interpreted broadly, a model can be big, either because it has a large number of equations, or because its equations are highly non-linear. If the modeller makes use of a system of linear equations (Johansen technique), the model can remain small in terms of its computing requirements, even though the number of equations may be several millions. When a system of non-linear equations is considered, size can become a problem, despite advances of the last decade in non-linear methods for solving general equilibrium models. This is because care must be taken in limiting the size of the constrained maximisation problem to be solved in each step of the non-linear solution method.

4.2 Model modification

By making use of a linear solution method, most revisions of the model are handled by making appropriate changes in the input-output and elasticity files, and simply re-running the solution programs. These procedures do not require the re-writing of solution algorithms. In contrast, models relying on non-linear solution routines have to take computing considerations in mind when revisions to the model have to be made.

4.3 Model Application

One of the advantages of Applied General Equilibrium models for policy applications is the ability to switch between exogenous and endogenous categories. This flexibility is greatly reduced in models where non-linear solution algorithms are adopted. In such models, the replacement of one endogenous variable with another will, in general, constitute a major model revision and will require extensive rewriting of solution algorithms.

5. THE EFFECT OF A PROPORTIONAL INCREASE IN GENERAL SALES TAX ON THE USE OF PRODUCTS WHICH ARE PRODUCED WITH A HIGH LEVEL OF CO2 EMISSION

As described in the introduction, the effects of a general sales tax on commodities, which are produced with simulation is concerned with the implications of the hypothetical policy change for aggregate employment, employment by occupation, the level of output in each industry in the model and aggregate growth. In order to test for a double dividend effect, government revenue is not allowed to increase. The revenue collected by the government with the indirect sales tax is redistributed in the form of tax cuts to each income group. The low income tax group receives the highest tax cut, while the highest income group receives the lowest tax cut.

5.1 Determining the sales tax rate increases

Ideally, the rate, at which the sales tax is to increase, is determined by examining the level of CO_2 emissions of each industry in the model. The level of emission, relative to the other industries, then determines the sales tax increase for a specific product. The product associated with the industry with the highest CO_2 emission has a increase of 10 percent in its general sales tax, and the product associated with industries with no CO_2 emission have a zero increase in its tax rate. Table 2 below indicate the relative CO_2 emissions of each industry which contributes significantly towards CO_2 pollution, as calculated, and summarised by Blignaut (2002) and summarise the suggested sales tax increases on the product associated with each industry.

Table 2: CO2 Emission of each industry in the model, and the sales tax increase on the commodities associated with the industry.

Industry	Relative CO2 Emission(%)	Sales tax increase
1. Agriculture	0	0
2. Gold Mining	0	0
3. Other Mining	0	0
4. Food	0	0
5. Beverages	0	0
6. Tobacco	0	0
7. Textile	0	0
8. Clothing	0	0
9. Leather	0	0
10. Footwear	0	0
11. Wood	0	0
12. Furniture	0	0
13. Paper	0	0
14. Printing	0	0
15. Chemical	33.6	5.4
16. Rubber	0	0
17. Plastic	0	0
18. Non Metal	0	0
19. Basic Metal	3.6	5.8
20. Fabric Metal	0	0
21. Machinery	0	0
22. Electric Machinery	0	0
23. Transport Equipment	0	0
24. Other Manufacturing	0	0
25. Electricity	62.5	10
26. Construction	0	0
27. Civil Engineering	0	0
28. Trade	00	0
29. Accommodation	0	0
30. Transport	0	0
31. Communication	0	0
32. Finance	0	0
33. Community Services	0	0
34. Government Industries.	0	0

It is clear from the above table that the major contributors towards CO_2 pollution are the electricity and chemical industries, which include ESKOM and SASOL respectively. Although the other industries do emit CO_2, it is such a small magnitude that we omit it from this simulation exercise. The products, which will be taxed, are therefore those products produced from the Electricity, Chemical and Metal industries. The income tax reductions which will result in a zero change in government revenue is summarised in table 3:

Table 3: Income tax rate reductions

Income group	Percentage decrease in marginal income tax rate
Q1	40
Q2	35
Q3	30
Q4	25
D5	20
D6	20

With the sales tax rates determined, the model can be closed and the results of the simulation reported

5.2 Closure of the model and simulation results.

The choice of exogenous variables characterises a simulation that allows for the analysis of the short run effect of the proposed policy change. In the short run, wages and capital stock will be fixed, allowing for a change in labour and the rate of return on capital. We further exogenise technological change variables and all relevant tax rates.

Table 3 summarise the result of the proposed tax changes on employment in each industry, and the output of each industry. Table 4 reports the macro-economic and welfare effect of the proposed policy change. Distinction is made between a simulation, which allows only for an increase in taxes (simulation 1), and a simulation in which we allow for an increase in sales taxes, but return the tax to households in the form of income tax cuts (simulation 2).

Table 3: Industry Specific effects of proposed policy change

	Output		Employment	
	Simulation 1	Simulation 2	Simulation 1	Simulation 2
1. Agriculture	-0.52	-0.66	-1.74	-221
2. Gold Mining	-4.17	-7.51	7.23	-12.84
3. Other Mining	-0.1	-3.02	-0.21	-5.83
4. Food	-0.69	-0.12	-0.97	-0.16
5. Beverages	-1.17	0.71	-3.63	2.23
6. Tobacco	-1.36	0.66	-2.27	1.1
7. Textile	-1.34	-3.1	-1.9	-4.4
8. Clothing	-1.52	0.29	-1.83	0.35
9. Leather	-1.85	-0.9	-2.91	-1.42
10. Footwear	-0.46	-1.33	-0.74	-2.13
11. Wood	-0.63	-1.64	-0.9	-2.35
12. Furniture	-1.85	0.72	-2.26	0.88
13. Paper	-0.49	-1.02	-1.54	-3.21
14. Printing	-1.88	0.4	-2.54	0.54
15. Chemical	-3.5	-3.1	-7	-6.21
16. Rubber	-1.01	-2.17	-1.59	-3.4
17. Plastic	-1.54	-1.05	-2.56	-1.75
18. Non Metal	-0.42	-1.21	-0.67	-1.95
19. Basic Metal	-0.11	-2.84	-0.23	-5.67
20. Fabric Metal	-0.43	-1.9	-0.54	-2.39
21. Machinery	-0.6	-1.53	-0.87	-2.21
22. Electric Machinery	-0.46	-1.87	-0.69	-3.76
23. Transport Equipment	-0.11	-0.56	-0.34	-2.76

24. Other Manufacturing	-0.09	-1.2	-0.21	-2.63
25. Electricity	-2.7	-1.9	-8.94	-6.65
26. Construction	0.04	0.09	0.04	-0.11
27. Civil Engineering	-0.19	-0.21	-0.24	-0.27
28. Trade	-1.74	0.41	-2.69	0.64
29. Accommodation	-0.99	-0.42	-1.45	-0.62
30. Transport	-1.25	-1.11	-2.03	-1.8
31. Communication	-1.14	0.02	-2.54	0.04
32. Finance	-0.93	-0.11	-1.95	-0.24
33. Community Services	-2.72	1.7	-3.75	2.36
34. Government Industries.	0.00	0.00	0.00	0.00
35. Servants	-3.95	3.32	-3.95	3.33

Table 4: Macroeconomic effect of policy proposals

	Simulation 1	Simulation 2
GDP Growth	-1.29	-0.72
Government Revenue	4.4	-0.25
Utility per Household: Q1	-477	1.93
Q2	-4.44	3.81
Q3	-4.15	4.53
Q4	-4.62	3.93
D9	-4.36	3.89
D10	-5.2.	2.93

6 INTERPRETING THE RESULTS

The general effect of an increase in sales tax on electricity, chemical and metal products is a decrease in both industry specific output and employment levels. It further result in a decrease in GDP growth and utility in each of the six household categories. However, the redistribution of the tax revenue to households by a decrease in marginal income tax rates, result in a scenario in which industry specific output and employment results are mixed. In some industries these variables decrease and in some it increases. GDP growth declines marginally, while utility increase in each of the income groups.

According to our model, the increase in the sales tax result in an increase in the price of electricity, chemical products and basic metals, for intermediate use, investment use, final consumption, exports and the government. In simulation 1, the increase in price result in both an income and substitution effect on demand in the economy, however, it seems as if the income effect has the overriding effect on all industries. As a consequence of the decline in household income, consumption expenditure of households decline (we have set the other demand components in the economy exogenous). A result of the decrease in consumption expenditure is that industries experience a decreasing demand, which in turn result in less employment across all industries and a further decline in income. As a result of the declining income and consumption patterns of households, utility levels decline.

In our second simulation in which we decrease the marginal tax rate across income groups, the substitution effect of the increase in the price of electricity, chemicals and base metals, result in an decrease in the demand for certain products, and an increase for other products as more expensive products are substituted for less expensive goods. This in turn leads to a decrease in employment in some industries, and an increase in others. The macroeconomic effect of such a policy is still a slight decline in GDP growth, however household utility increase across all income groups, which can be interpreted as an increase in the welfare of society.