Constructing a greenhouse gas emissions database using energy balances: the case of South Africa 1998

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Abstract

This paper discusses the procedures and results of constructing a greenhouse gas (GHG) emissions database for South Africa, using the official national energy balance for 1998. In doing so, the paper offers a snapshot of the South African energy supply and demand profile and encompasses greenhouse gas emissions profiles, disaggregated into 40 economic sectors, for the reference year. For convenience, energy supply and use are reported in both native units and terra joule (TJ) while emissions are expressed in carbon dioxide equivalents and reported in giga-gram (Gg). While carbon dioxide is the leading contributor to global anthropogenic GHG emissions, the inclusion of methane and nitrous oxide offers considerable richness to the analysis of climate change policies. Applying the energy balances, it was possible to compile a comprehensive emissions database using a consistent methodology across all sectors of the economy. The database allows the economic analyst to model various economic policies, either i) with fuel as an input to production, or ii) with the consumption of fuel or the emissions generated during combustion, as the base of the analysis. The dominant role of coal as source of energy, with a total primary energy supply (TPES) of 3.3 million TJ (or 70 per cent of the total TPES), is clearly shown. Emissions from coal combustion (263,783 Gg of carbon dioxide equivalents or 74.7 per cent of total emissions) are hence the largest contributor to total emissions, estimated to be 352, 932 Gg carbon dioxide equivalents.

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1. Introduction

Developing countries, also known as non-Annex I parties according to the Kyoto protocol, have "common but differentiated" responsibilities as outlined in Article 4 (a-j) of the UNFCC (UNFCCC 1999). This means that they are neither obligated to reduce greenhouse gas (GHG) emissions, nor will they be required to do so even if the Kyoto Protocol becomes mandatory during the first commitment period (2008-2012). At the same time, increasing pressure is placed on developing countries to share the burden of GHG reduction. This might result in non-Annex I countries having emission reduction commitments during the second commitment period after 2012. Part of the reluctance of developing countries to participate in global climate change initiatives stems from a lack of empirical research to inform policy. This lack of solid empirical work can partially be explained by the lack of official greenhouse gas emissions inventories that are both timely and reliable.

The question that now arises is whether it is possible to use the national energy balance, (published annually by national authorities in charge of energy statistics) as a source of information to calculate an emissions database that could be linked to economic sectors. This database could then potentially be used in economic analysis and modelling. This is the question that this study addresses, with a focus on South Africa. The next section provides background information regarding existing GHG emissions data and argues for the development of a comprehensive and consistent methodology that could be used repeatedly at a low cost (but with a high degree of accuracy), to compile an unofficial greenhouse gas emissions inventory. Thereafter the methodology followed to calculate the new emissions database is discussed, followed by the study results and a discussion thereof. A conclusion completes the paper.

2. Background

Despite the importance of data on greenhouse gas (GHG) emissions, no official GHG emissions inventory beyond 1994 exists in South Africa. The summary of the emissions inventory is provided in Table 1. From this, it is clear that emissions of carbon dioxide (CO2) are by far the greatest of all the greenhouse gas emissions, though the global warming potential of the other two gases, methane (CH4) and nitrous oxide (N2O), is significantly higher. It is also clear that the energy sector is the main emitter of GHG emissions. This is mainly the result of the combustion of fossil fuels, especially coal. Notwithstanding the fact that the information is rather dated, the other concern regarding this inventory is that it does not precisely indicate the source of fuel, the fuel type, the sector combusting the fuel or the purpose of fuel combustion. This is the type of analysis, or data mapping, required for an economic analysis of the impact of various policies aimed at mitigating the country's GHG emissions. This analysis could include the use of economy-wide modelling techniques such as computable general equilibrium (CGE) Models, Social Accounting Matrix (SAM) Impact Models and Input-Output Models.

As far as the current South African literature on emission data is concerned, there are a number of studies that offer sector specific emissions data. These include studies focusing on the transport sector (Gaffen et al. 2000 and Freeman et al. 2000), the electricity sector (Spalding-Fecher et al. 2000), the liquid fuel sector (Lloyd et al. 2000) and the mining sector (Clement and Foster 2000). Other studies focusing on the manufacturing sector include those by Visser et al. (2000), Trikam (2002), Blignaut and King (2002) and Blignaut and Zunckel (2004).

All of these have in common the fact that they needed an emissions database for the respective economic sectors and had to rely on various different methodologies and sources of data to compile a database for their specific sectors of interest. This was advantageous in providing invaluable information regarding specific sectors, at that time. The disadvantage, however, is that, since these studies are based on different methodologies, base years and sources, they are not comparable. Also, trying to get a comprehensive picture of the emissions profile of the country, based on such a variety of sector-specific studies is very difficult and could ultimately lead to costly mistakes.

This leaves the economy-wide economic analyst in a precarious position: i) either use the dated, but comprehensive, national GHG inventory database and adapt that to conform to the international industrial sector classification used in compiling an input-output or social accounting matrix, or ii) use the more recent, but fragmented, sectoral studies to construct a new database. Neither solution is optimal, hence the need for a comprehensive and internally consistent GHG emissions database. Earlier attempts along the lines of what is presented in this paper were made by Foster (1998). Although Foster (1998) made greater use of primary data sources, the approach did not allow the mapping of emissions by fuel and sector in a way that is inherently consistent across sectors and fuels.

Table 1 Official GHG emissions inventory.

	CO_2		CH_4		N_2O	
	1990	1994	1990	1994	1990	1994
Energy	256764	287851	349	376	5	6
- Energy industries	156373	167817	1	0	3	3
- Industry	47026	53186	6	6	1	1
- Transport	30779	42717	9	11	1	2
- Commercial	11844	780	1	0	0	0
- Residential	7542	7397	9	1	0	0
- Agriculture	3200	15954	0	31	0	1
- Fugitive emissions			324	327		
Industrial processes	31190	30010	3	1	5	6
- Mineral products	5478	5331				
- Chemical industry	3936	3856	3	1	5	6
- Metal production	21776	20823				
Agriculture			1014	937	62	51
- Enteric fermation			917	844		
- Manure management			83	78	1	0
- Agricultural soils					60	50
- Savannah burning			13	13	1	1
- Agricultural residues burning			2	2	0	0
Land use change and forestry	-16982	-18616				
- Changes in biomass	-13641	-10886				

	CO_2		CH_4		N_2O	
	1990	1994	1990	1994	1990	1994
- Soil removals	-3341	-7730				
Waste			666	743	2	3
- Solid waste on land			647	722		
-Waste water handling			19	21	2	3
International bunkers	7195	10220				

Source: RSA (2000).

3. Methodology

3.1 General

In light of the difficulties mentioned above, a GHG emissions database has been compiled using the national energy balance as published by the Department of Mineral and Energy (DME 2000). These balances are compiled on an annual basis and provide data on the production, consumption, exports, imports and stock changes of black coal, brown coal, briquettes, coke, crude oil, a variety of petroleum products, natural gas, and electricity production. The published tables reconcile national supply figures for each fuel, calculated from indigenous production, exports and imports, with the detailed sector-by-sector energy consumption figures. Reconciliation is achieved in both native units (i.e. tons, MWh and kl) and standardised energy units (i.e. tons of oil equivalent, and TJ).

This information has been used to calculate the CO_2, CH_4 and N_2O emissions per sector per fuel group for 1998 using various emission factors (see discussion below). 1998 was selected as the reference year, since this corresponds to the latest available official South African social accounting matrix (SAM), but the same methodology could easily be applied to any energy balance. This methodology allowed the mapping of emissions by fuel and sector in a way that is inherently consistent across sectors and fuels, and amenable to the structure of the South African SAM (see Table 2 for the sectoral cross tabulation). This implies that economic policy analysis through integrated environmental-economic modelling is possible. Not only could emissions by fuel and sector be mapped, but also the energy consumption by fuel and sector in either a standardised unit (e.g. TJ) or native units.

Table 2 Sectoral cross tabulation: SAM and National Energy Balance.

Energy Balance sector	Treatment in the SAM
Iron and Steel	Iron and steel
Chemical and Petrochemical	Split into chemical and petroleum products according to the use of each fuel type by each sector
Non-Ferrous Metals	Nonferrous metals
Non-Metallic Minerals	Non-metallic minerals
Transport Equipment	Transport equipment
Machinery	Machinery
Mining and Quarrying	Split into gold, coal, crude oil and gas and other mining according to the use of each fuel type by each sub-sector
Food and Tobacco	Food

Energy Balance sector	Treatment in the SAM
Paper Pulp and Print	Paper, pulp and wood
Wood and Wood Products	Paper, pulp and wood
Construction	Construction
Textile and Leather	Textile
Non-specified (Industry)	Other manufactures
Transport Sector	Transport services
Agriculture	Split into irrigated and dry field, irrigated and dry horticulture, livestock, forestry and other agriculture according to the use of each fuel type by each sub-sector
Commerce and Public Services	Split into the various service sectors according to the use of each fuel type by each sub-sector
Residential	Allocated to households
Non-specified (Other)	Other service activities

Source: Own analysis.

The fossil fuels contributing to GHG emissions included in the database comprise coal, oil and natural gas. Most of the emissions from oil are attributed to the consumption of petroleum products, because oil is largely transformed into these products. Only the emissions by oil refineries during the transformation process are attributed to oil. Similarly, to avoid ‘double counting’, only the generation of electricity, and not its consumption, contributes to emissions. Currently, the database does not account for non-combustion GHG emissions. Non-combustion emissions of GHG comprise fugitive emissions from oil and natural gas systems, and emissions from industrial processes such as aluminium production and cement manufacturing. Neither does the database include emissions from burning savannahs and agricultural residues.

In the database, emissions of each GHG are expressed in carbon dioxide equivalents, based on the ‘global warming potentials’, which measure the relative radiative forcing of different GHG over a specific period. These global warming potentials over a one century time horizon are 1, 21 and 310 for carbon dioxide, methane and nitrous oxide respectively, as recommended by the International Panel on Climate Change (IPCC 1996).

3.2 Carbon dioxide emissions

Coal-based CO_2-emissions

The carbon contained in fossil fuels oxidises and transforms into mainly CO_2 during combustion. Currently, there is no technology that can successfully mitigate CO_2 emissions. The emission of CO_2 depends on the quantity and type of the fuel used and follows the laws of material balance and thermodynamics. The amount of CO_2 emitted can be calculated using two different approaches, namely the reference and the sectoral approaches. Using the reference approach, the input data are production, import, export, international bunkers and stock change for primary and secondary fuel. The more detailed approach involves the calculation of emissions using fuel consumption in different energy sub-sectors. The difference between the reference and the sectoral approaches should be relatively small. This study applies the sectoral approach to calculate the carbon dioxide emissions from the combustion of fossil fuels (see IEA 2001 for details), with some modification.

Emissions of CO_2 from coal combustion were calculated by multiplying the quantity of coal consumed in each sector by an effective emission factor for coal in that sector. To compute CO_2 emission factors for coal combustion, the coal consumption and resulting CO_2 emissions for 2000 reported in Blignaut and King (2002) were used, and it was assumed that these factors were relevant for 1998. The implied emission factors are shown in Table 3.

Table 3 Coal emission factors.

Sector	Emission factor t CO2/TJ
Iron and steel	90.92
Agriculture	92.96
Iron and steel	92.73
Non Specified transport	91.05
Chemical industries	92.07
Commerce and public services, residential, non-specified other	93.64
Mining and quarrying	90.60
Non-metallic	90.72
Petrochemical	50.21
Auto-producer electricity plant	70.23
Public electricity plant	78.71

Source: Own calculations based on Blignaut and King (2002) as reported in Blignaut and Zunckel (2004).

Non-coal-based CO_2-emissions

Carbon dioxide emissions from non-coal fossil fuel sources have been calculated in a similar way to that of coal, namely by multiplying the fuel consumption in each sector by the respective emission factor. The basis for the estimate is the fuel used in different energy sectors, grouped into the fossil fuels categories according to its aggregate condition, namely crude oil, petrol, diesel, other petroleum, gas and renewables. Data about quantities of the fuel used are taken from the energy balance in TJ (DME 2000).

The carbon content factors used for calculations are distinguished by fuel source and obtained from IPCC guidelines on emission factors. The factors applied to the different fuel categories are shown in Table 4.

Table 4 Carbon emission factors used for other energy sources.

Liquid Fossil	20.0t C/TJ Crude oil
	18.9t C/TJ Petrol
	20.2t C/TJ Diesel
	19.5t C/TJ Jet kerosene
	19.6t C/TJ Other kerosene
	20.0t C/TJ Shale oil
	21.1t C/TJ Residual fuel oil
	17.2t C/TJ LPG
	16.8t C/TJ Ethane

	20t C/TJ Naphta
	22.0t C/TJ Bitumen
	20.0t C/TJ Lubricants
	27.5t C/TJ Petroleum coke
	20.0t C/TJ Refinery feedstocks
	18.2t C/TJ Refinery gas
	20.0t C/TJ Other oil
Gaseous Fossil	15.3t C/TJ Natural gas (dry)
Biomass	29.9t C/TJ Solid biomass
	20.0t C/TJ Liquid biomass
	30.6t C/TJ Gas biomass

Source: IPCC 1995.

General

In short, the carbon dioxide emission factors are calculated by multiplying the carbon emission factors (adjusted for oxidation) of a particular fuel by 3.6667 kg CO_2 per kilogram of carbon, and then multiplying that product by the energy amount of the fuel consumed. The steps followed are depicted by the following equation:

$$CO_2 = \sum \left[ACTIVITY \times EF \times \frac{44}{12} \right]$$

where

CO_2 = carbon dioxide emissions from fossil fuel combustion (in Gg)

ACTIVITY = fuel consumption converted to TJ

EF = emission factor, equal to carbon coefficient multiplied by oxidation factor, expressed as t/TJ

$\frac{44}{12}$ = molecular weight ratio of CO_2 to carbon.

Because not all carbon is oxidized, a relevant oxidation factor is applied. The oxidation factors used are shown in Table 5.

Table 5 Oxidation factors for CO_2.

Fuel	Utilisation category	Oxidation factor
Coal	Electricity generation	99%[(a)]
	Manufacturing industry	98%[(b)]
	Commercial, residential and other	95%[(c)]
Oil	All	99%[(c)]
Gas	All	99.5%[(d)]

Sources:

(a) IPCC (1995, Volume 3) default value.

(b) IPCC (1995, Volume 3) default value for “best practice”. Depending on maintenance procedures and efficiency, IPCC proposes a range of 90-98% for stoker fired industrial boilers.

(C) IPCC (1995, Volume 3) default values.

(d) IPCC (1995, Volume 3) default values.

3.3 Non-carbon dioxide emissions

As discussed above, the sources of methane and nitrous oxide emissions covered include combustion sources only. They were computed using the following approach:

$$GAS = ACTIVITY * EF$$

where

Activity fuel consumption converted to TJ

EF emission factor, expressed as kg/TJ

Methane

There are a number of ways suggested in the literature to account for the emission of methane. There are emission factors from IPCC IGES database, IPCC default emission factors or even the option of using the average from a cluster of countries. This study used the IPCC default guidelines (see Table 6) to be consistent with the methodology used for carbon. While it is generally desirable to use country-specific emission factors, data limitations have dictated the use of this methodology.

Table 6 Emission factors for CH_4 (kg/TJ).

Sector	Emission factor kg CH4/TJ
Energy Industries	
- Liquid fuels	3
- Solid fuels	1
- Gaseous fuels	1
- Waste	30
Manufacturing Industries	
- Liquid fuels	2
- Solid fuels	10
- Gaseous fuels	5
- Waste	30
Other Sectors	
- Liquid fuels	10
- Solid fuels	300
- Gaseous fuels	5
- Biomass and waste	300

Source: IPCC 1996.

Nitrous Oxide

For nitrous oxide from the transport sector, the IPCC default emission factor values have been used. The IPCC gives a constant emission factor of 0.6 kg/TJ for both petrol and diesel. However, a footnote to the gasoline emission factor states that when there are a significant number of cars with three-way catalysts in the country, road transport emission factors should be increased accordingly. To take into account expected increases in emissions over time as the use of catalysts increases, one has to consider changes in technologies. It has been assumed that, while in 1990 all cars in South Africa were non-catalyst-controlled (with an emission factor of 1.4 kg/TJ), in 1998 all cars were equipped with three-way catalysts (with an emission factor of 7.3 kg/TJ). The emission factor for electricity is computed from actual emission figures reported in Eskom (2000) and works out to be 2.86 kg N_2O/TJ. The emission parameters used are summarised in Table 7.

Table 7 Emission parameters for N2O emissions.

Fuel	Emission factor
LPG	0.1kg N_2O/TJ
Natural gas	0.1kg N_2O/TJ
Electricity	2.86 kg N_2O/TJ
Diesel	0.6kg N2O/TJ
Petrol	7.3 kg N_2O/TJ

Sources: IPCC 1996 and Eskom 2000.

4. Results: energy and greenhouse gas emission inventory for South Africa: 1998

Total primary energy supply (TPES) comprises indigenous production plus imports minus exports minus international marine bunkers minus stock changes. Table 8 illustrates the main sources of energy in South Africa in 1998 in TJ. The dominant role of coal in the economy is evident from the table; it contributes more than 70 per cent of the country's energy needs. Approximately 25 per cent of the country's energy needs are met by crude oil, while natural gas, nuclear, renewable energy and biomass combined contribute a total of less than 10 per cent. Also indicated in the table is that petroleum and crude oil are mainly imported while the other fuels originate mainly from domestic sources.

The energy available for final consumption is derived after adjusting for i) statistical differences and ii) energy used or being made available during the energy transformation processes (i.e. the conversion of coal to electricity through coal-fired power stations and crude oil to petroleum products through oil refineries) (see Table 8 also). Figure 1 indicates the share of final demand by fuel used in South Africa during 1998. Electricity accounted for approximately 24 per cent of total final demand energy, while petroleum met 33 per cent of final demand energy needs. Coal accounted for 31 per cent of final demand and renewables and gas for 11 per cent.

Table 9 shows the final demand for energy in TJ and in native units, where applicable, for 40-sectors. Taken as an aggregate, the industrial sector is the largest consumer of total energy, accounting for 44.2 per cent of all energy consumed in South Africa. Services accounts for 26.2 per cent of all energy consumed while agriculture demands 5 per cent, mining 8 per cent and the residential sector demands 16 per cent. Taken individually, the trade sector is the largest consumer of energy, consuming 20.6 per cent of all energy, followed by the residential sector with 16.3 per cent. Iron and steel, petroleum products and other metal products largely account for industrial consumption.

Table 8 South Africa's Total Primary Energy Supply (TJ).

	Coal	Crude Oil	Petroleum	Gas	Nuclear	Hydro	Renewables	Electricity	Total
Indigenous production	5,278,319	293,876	-	53,983	148,375	5,742	237,400	-	6,017,694
Imports	36,147	897,696	40,948	-	-	-	-	8,550	983,342
Exports	-1,716,393	-28,925	-147,573	-	-	-	-	-16,315	-1,909,207
Intl. marine bunkers	-	-	-122,341	-	-	-	-	-	-122,341
Stock changes	-329,875	-	-	-	-	-	-	-	-329,875
Total primary energy supply (TPES)	3,268,198	1,162,648	-228,966	53,983	148,375	5,742	237,400	-7,765	4,639,614
TPES %	70.4	25.1	-4.9	1.2	3.2	0.1	5.1	-0.1	100
Energy transformation[1]	-2,783,868	-1,162,648	998,318	-22,791	-148,375	-5,742	-47,000	622,322	-2,549,784
Statistical difference[2]	241,939	0	-24,761	43,651	0	0	0	-43,406	217,423
Total final consumption	726,269	0	744,591	74,843	0	0	190,400	571,151	2,307,253

Source: DME (2000) and own calculations.

Notes:

1 A portion of the TPES is transformed into other forms of energy, e.g. coal and crude oil to electricity and petroleum products respectively. Energy used during this transformation process is therefore not part of the final consumption component. As such, petroleum and electricity are indicated as the recipient sectors by a positive value and the source sectors (coal, crude oil, nuclear, hydro, gas and renewables) by a negative sign. During the transformation process there is a net energy loss of 2.55 million TJ, as indicated in the last column.

2 The difference between the TPES plus energy transformation and the total final consumption.

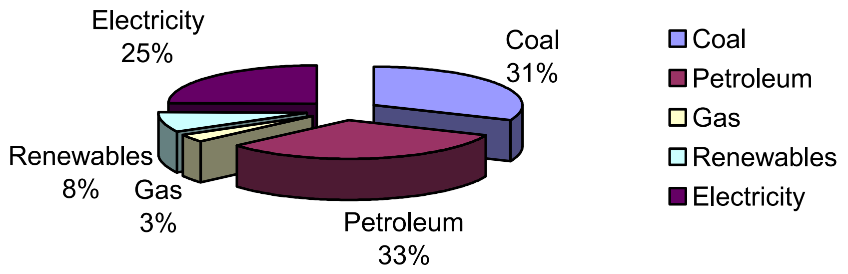

Figure 1 Share of final demand for energy by fuel type in 1998:%.

Source: Table 8.

It is evident that the residential sector, gold mining, iron and steel, other metal products and non-ferrous metals consume the lion's share of electricity. In contrast, agriculture is a relatively small consumer of electricity. The petrochemical industry, iron and steel and other metal products dominate the demand for coal. The rest of the sectors are small consumers spread across the economy. The trade sector demands 61 per cent of petroleum products. Agriculture is also a fairly important consumer of petroleum products. Gas is mainly consumed by the iron and steel industry (almost 79 per cent). The final demand for renewables is exclusively accounted for by the residential sector.

Table 10 shows emissions in carbon dioxide equivalents for 1998 by sector and source of fuel. Of the total amount of CO_2 equivalent emissions of 352, 932 Gg, coal dominates the emissions as a source, contributing 263, 783 Gg of CO_2-equivalent or 74.7 per cent of the total emissions. This is followed by petroleum products with 53, 744 Gg or 15.2 per cent, then renewables with 6.6 per cent, and then crude oil and gas with 3.4 per cent. Emissions that occur during energy transformation and the final consumption of the various fuel sources are taken into consideration. To avoid 'double counting', electricity is not viewed as a fuel source in this respect, since emissions during the final consumption of electricity are considered to be zero. Electricity is viewed as a sector that consumes fuel.

Electricity generation (65.9 per cent) and petroleum refineries (20.4 per cent) dominate emissions from the combustion of coal, as also indicated in Table 10. These two sectors therefore contribute to more than 86 per cent of total emissions from the combustion of coal. Emissions from the combustion of petroleum are dominated by the trade sector (60.1 per cent), more specifically the retail sales of petroleum.

Emissions from crude oil and gas are mainly concentrated in the petroleum refineries (60.1 per cent) and iron and steel industries (27.2 per cent). The former mainly converts crude oil to petroleum and the latter uses gas. It should be noted that emissions are allocated to the sector at the point of combustion.

Therefore, the emissions allocated to the petroleum refineries are emissions that occur during the refinery process. The embedded carbon in the fuel is only emitted during the combustion of the fuel, mainly through motor vehicles.

Table 9 Final demand for energy by sector and fuel in TJ, native unit and share (%).

	Coal			Petroleum		
	TJ	T	%	TJ	kl	%
Irrigated field	1,124	41,621	0.2	11,239	307,137	1.5
Dry field	3,772	139,719	0.5	37,742	1,031,404	4.9
Irrigated horticulture	1	20	0	14,425	394,191	1.9
Dry horticulture	1	21	0	3,885	106,161	0.5
Livestock	1	19	0	17,760	485,326	2.3
Forestry	0	13	0	0	0	0
Other agriculture	59	2,173	0	9,099	248,646	1.2
Coal	284	10,526	0	12,929	354,158	1.7
Gold	6,233	230,856	0.9	9,257	253,574	1.2
Crude, pet. & gas	0	2	0	3,766	103,174	0.5
Other mining	34,466	1,276,516	4.7	14,897	408,066	1.9
Food	0	0	0	0	0	0
Textiles	0	0	0	0	0	0
Footwear	0	0	0	399	10,783	0.1
Other chemical & rubber	8,585	317,966	1.2	0	0	0
Petroleum refineries	253,359	9,383,664	34.8	0	0	0
Othr non-metal. minerals	33,990	1,258,880	4.7	0	0	0
Iron & steel	181,673	6,767,902	25.1	0	0	0
Non-ferrous metals	0	0	0	0	0	0
Other metal products	89,253	3,303,538	12.3	16,289	439,999	2.1
Other machinery	0	0	0	0	0	0
Electrical machinery	0	0	0	14,856	401,284	1.9
Radio	0	0	0	2,016	54,466	0.3
Transport equipment	0	0	0	0	0	0
Wood, pulp & paper	0	0	0	0	0	0
Other manufacturing	37,179	1,376,112	5.1	10,045	271,324	1.3
Electricity	0	0	0	0	0	0
Water	10,525	389,798	1.4	21	573	0
Construction	10	387	0	21,647	590,896	2.8
Trade	486	18,013	0.1	449,352	12,791,600	61.1
Hotels	876	32,442	0.1	24	648	0
Transport services	1,396	51,707	0.2	52,632	1,494,073	7.1
Communication	0	0	0	246	6,638	0
Financial institutions	0	0	0	108	2,901	0
Real estate	0	0	0	176	4,749	0
Business activities	0	0	0	121	3,273	0
General government	7,493	277,537	1	14,355	408,067	1.9
Health sector	4,612	170,807	0.6	215	5,794	0
Other service activities	409	15,142	0.1	56	1,512	0
Residential	50,483	1,869,744	6.9	27,033	766,197	3.7
Total	726,269	26,935,123	100	744,591	20,946,615	100

Source: Own calculations based on DME (2000).

Table 9 Continued.

	Gas		Renewables		Electricity			Total	
	TJ	%	TJ	%	TJ	MWh	%	TJ	%
Irrigated field	0	0	0	0	1,973	547,974	0.3	14,336	0.6
Dry field	0	0	0	0	6,625	1,840,164	1.2	48,139	2.1
Irrigated horticulture	0	0	0	0	3,574	992,796	0.6	17,999	0.8
Dry horticulture	0	0	0	0	963	267,375	0.2	4,848	0.2
Livestock	0	0	0	0	4,451	1,236,380	0.8	22,211	1
Forestry	0	0	0	0	771	214,045	0.1	771	0
Other agriculture	0	0	0	0	3,049	846,807	0.5	12,206	0.5
Coal	56	0.1	0	0	11,029	3,063,574	1.9	24,298	1.1
Gold	123	0.2	0	0	69,117	19,199,242	12.1	84,731	3.7
Crude, pet. & gas	193	0.3	0	0	25	7,057	0	3,985	0.2
Other mining	126	0.2	0	0	25,550	7,097,101	4.5	75,039	3.3
Food	1,154	1.5	0	0	2,081	578,116	0.4	3,235	0.1
Textiles	18	0	0	0	1,342	372,749	0.2	1,360	0.1
Footwear	0	0	0	0	1,735	482,002	0.3	2,134	0.1
Other chemical & rubber	313	0.4	0	0	5,077	1,410,337	0.9	13,976	0.6
Petroleum refineries	2,738	3.7	0	0	4,390	1,219,413	0.8	260,487	11.3
Othr non-metal. minerals	6,314	8.4	0	0	4,159	1,155,161	0.7	44,462	1.9
Iron & steel	58,980	78.8	0	0	67,914	18,865,014	11.9	308,567	13.4
Non-ferrous metals	957	1.3	0	0	53,170	14,769,314	9.3	54,127	2.3
Other metal products	0	0	0	0	79,970	22,213,943	14	185,512	8
Other machinery	604	0.8	0	0	133	36,875	0	737	0
Electrical machinery	0	0	0	0	18,884	5,245,503	3.3	33,740	1.5
Radio	0	0	0	0	4,790	1,330,642	0.8	6,807	0.3
Transport equipment	106	0.1	0	0	55	15,147	0	160	0
Wood, pulp & paper	541	0.7	0	0	5,986	1,662,673	1	6,526	0.3
Other manufacturing	2,501	3.3	0	0	11,831	3,286,262	2.1	61,555	2.7
Electricity	0	0	0	0	0	0	0	0	0
Water	0	0	0	0	3,387	940,745	0.6	13,932	0.6
Construction	0	0	0	0	350	97,290	0.1	22,008	1
Trade	10	0	0	0	25,775	7,159,615	4.5	475,623	20.6
Hotels	0	0	0	0	5,271	1,464,032	0.9	6,170	0.3
Transport services	77	0.1	0	0	12,476	3,465,541	2.2	66,581	2.9
Communication	0	0	0	0	5,786	1,607,124	1	6,032	0.3
Financial institutions	0	0	0	0	4,760	1,322,227	0.8	4,868	0.2
Real estate	11	0	0	0	3,881	1,078,060	0.7	4,069	0.2
Business activities	0	0	0	0	466	129,568	0.1	588	0
General government	19	0	0	0	3,595	998,640	0.6	25,463	1.1
Health sector	0	0	0	0	2,407	668,637	0.4	7,234	0.3
Other service activities	0	0	0	0	5,770	1,602,712	1	6,235	0.3
Residential	0	0	190,400	100	108,587	30,163,089	19	376,504	16.3
Total	74,843	100	190,400	100	571,151	158,652,942	100	2,307,253	100

Source: Own calculations based on DME (2000).

Private petroleum sales are allocated to the retail trade sector. This distinction is essential to ensure that there is no 'double counting'. Emissions from renewable sources are only concentrated in the electricity and residential sectors. With regard to the former, this reflects the use of renewable materials for the generation of electricity for own consumption by industries (such as in the paper and pulp and automotive industries). In total, electricity generation, petroleum refineries and the retail trade sectors account for 77.1 per cent of emissions.

Table 10 Emissions by sector and source: Gg CO_2-equivalent and %.

	Coal		Petroleum		Crude oil and gas		Renewables		Total	
	Gg	%	Gg	%	Gg	%	Gg	%	Gg	%
Irrigated field	86	0.0	818	1.5	0	0.0	0	0.0	904	0.3
Dry field	290	0.1	2,746	5.1	0	0.0	0	0.0	3,036	0.9
Irrigated horticulture	0	0.0	1,049	2.0	0	0.0	0	0.0	1,050	0.3
Dry horticulture	0	0.0	283	0.5	0	0.0	0	0.0	283	0.1
Livestock	0	0.0	1,292	2.4	0	0.0	0	0.0	1,292	0.4
Forestry	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Other agriculture	5	0.0	662	1.2	0	0.0	0	0.0	666	0.2
Coal	22	0.0	940	1.7	3	0.0	0	0.0	965	0.3
Gold	477	0.2	673	1.3	7	0.1	0	0.0	1,157	0.3
Crude, pet. & gas	0	0.0	274	0.5	11	0.1	0	0.0	285	0.1
Other mining	2,636	1.0	1,083	2.0	7	0.1	0	0.0	3,726	1.1
Food	0	0.0	0	0.0	64	0.5	0	0.0	64	0.0
Textiles	0	0.0	0	0.0	1	0.0	0	0.0	1	0.0
Footwear	0	0.0	29	0.1	0	0.0	0	0.0	29	0.0
Other chemical & rubber	463	0.2	0	0.0	834	6.9	0	0.0	1,297	0.4
Petroleum refineries	53,704	20.4	0	0.0	7,286	60.1	0	0.0	60,990	17.3
Other non-metal minerals	2,603	1.0	0	0.0	353	2.9	0	0.0	2,955	0.8
Iron & steel	14,080	5.3	0	0.0	3,295	27.2	0	0.0	17,376	4.9
Non-ferrous metals	0	0.0	0	0.0	53	0.4	0	0.0	53	0.0
Other metal products	6,859	2.6	1,192	2.2	0	0.0	0	0.0	8,052	2.3
Other machinery	0	0.0	0	0.0	34	0.3	0	0.0	34	0.0
Electrical machinery	0	0.0	1,087	2.0	0	0.0	0	0.0	1,087	0.3
Radio	0	0.0	148	0.3	0	0.0	0	0.0	148	0.0
Transport equipment	0	0.0	0	0.0	6	0.0	0	0.0	6	0.0
Wood, pulp & paper	0	0.0	0	0.0	30	0.2	0	0.0	30	0.0
Other manufacturing	2,857	1.1	735	1.4	140	1.2	0	0.0	3,732	1.1
Electricity	173,802	65.9	0	0.0	0	0.0	4,608	19.8	178,409	50.6
Water	814	0.3	2	0.0	0	0.0	0	0.0	816	0.2
Construction	1	0.0	1,575	2.9	0	0.0	0	0.0	1,576	0.4
Trade	37	0.0	32,291	60.1	1	0.0	0	0.0	32,329	9.2
Hotels	68	0.0	2	0.0	0	0.0	0	0.0	69	0.0
Transport services	108	0.0	3,785	7.0	4	0.0	0	0.0	3,898	1.1
Communication	0	0.0	18	0.0	0	0.0	0	0.0	18	0.0
Financial institutions	0	0.0	8	0.0	0	0.0	0	0.0	8	0.0
Real estate	0	0.0	13	0.0	1	0.0	0	0.0	14	0.0
Business activities	0	0.0	9	0.0	0	0.0	0	0.0	9	0.0
General government	580	0.2	1,032	1.9	1	0.0	0	0.0	1,613	0.5
Health sector	357	0.1	16	0.0	0	0.0	0	0.0	372	0.1
Other service activities	32	0.0	4	0.0	0	0.0	0	0.0	36	0.0
Residential	3,904	1.5	1,979	3.7	0	0.0	18,666	80.2	24,549	7.0
Total	263,783	100.0	53,744	100.0	12,132	100.0	23,274	100.0	352,932	100.0

Source: Own calculations.

Two questions now present themselves. Firstly: Are these numbers important? Secondly: What is the extent of their importance? The answer to the former should be ‘yes, when compared to other countries’. According to Winkler *et al.* (2001), South Africa’s emissions intensity is about 240 per cent above world average, and the highest of the all the developing countries considered (see Table 11). In 1995, the country’s emissions intensity was 2.82 kg CO_2 per purchase power parity adjusted 1990$ of GDP produced, compared to a world average of 0.87 and a non-OECD average of 1.99. In terms of emissions per capita, South Africa is 189 per cent above the world average of 1.07 tons of carbon per person. This compares extremely unfavourably with the emissions per capita of Argentina (95 per cent of world average), China’s 67 per cent, India’s 25 per cent, Nigeria’s 21 per cent and Brazil’s 41 per cent. Though these are populous countries, they do represent countries of a comparable state of development.

Table 11 Selected key ratios concerning greenhouse gas emissions and welfare levels: a country comparison with world averages.

	Key characteristic	**South Africa**	**Argentina**	**China**	**India**	**Nigeria**	**Brazil**	**World average**	
								Value	**Units**
Share of world (%)	Total CO_2 emissions per year (1995)	1.37%	0.58%	14.30%	4.07%	0.41%	1.12%	6,098	Million tons carbon
	CO_2 emissions cumulative (1915-1995)	1.14%	0.50%	6.70%	1.95%	0.23%	0.69%	227,440	Million tons carbon
	Population	0.73%	0.61%	21.49%	16.11%	1.97%	2.74%	5,684.78	Millions
	Total GDP for 1995	0.57%	0.78%	9.58%	3.43%	0.39%	2.26%	37,877,689	Millions of 1995 Int$ -- PPP
Relative to world average	Gross domestic product (GDP) per capita	79%	127%	45%	21%	20%	83%	6,663	1995 $ per year
	Emissions intensity ($C0_2$ per GDP)	240%	75%	149%	119%	105%	49%	0.16	kg of C / $ of GDP
	Emissions per capita	189%	95%	67%	25%	21%	41%	1.07	tons of C per person

Source: Winkler *et al.* (2001).

5. Concluding remarks

A greenhouse gas emissions database has been constructed, based on the energy balance of South Africa and various emission factors. The sectoral dimensions of the database are adjusted to those of the 1998 social accounting matrix of South Africa. This enables the economic analyst to model various policies using a variety of applied modelling techniques.

Based on the information contained in the database, greenhouse gas emissions from combustion sources amounted to 352, 932 Gg in 1998, with the electricity generation sector contributing 178, 409 Gg or almost 51 per cent, followed by the petroleum refineries which contributed 60, 990 Gg or 17.3 per cent of the total. It has also been indicated that these values are significant in a global context, relative to other developing countries. This necessitates the use of economic modelling techniques to find the optimum policy scenario in an effort to reduce the country's carbon footprint.

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