Greenhouse gas emissions from South Africa

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South African greenhouse gas emissions contributed about 1.2% to the global increase in the greenhouse effect in 1988. South Africa generated trace gases with a radiation absorption potential over a 20-year period equivalent to 534 million tons of CO_2. These gases included 350 Tg CO_2 (65.6% of the effect), 183 Tg CH_4 (34.2%) and 1.2 Tg N_2O (0.2%). The mining and burning of coal contributed more than 80% of the greenhouse gas emissions from South African territory.

The burning of fossil fuels and clearing of natural vegetation have resulted in sharply increasing atmospheric concentrations of gases such as CO_2, CH_4, N_2O, NO_x, CO and NMVOC (non-methane volatile organic carbon) since the beginning of the Industrial Revolution two centuries ago. The first three are greenhouse gases, which are nearly transparent to incoming solar radiation, but absorb the outgoing re-radiation from the earth. CH_4, NO_x and CO interact in the troposhere to form ozone (O_3), which is both a greenhouse gas and a pollutant. The growing worldwide concern that alterations to the composition of the atmosphere could lead to a global climate change has led to the signing of the Framework Convention on Climate Change (FCCC) by more than 150 nations. The FCCC seeks to regulate the emissions of potentially climate-altering gases to the atmosphere.

South Africa signed the treaty in 1993 and is in the process of deciding whether to ratify it or not. Countries which have signed and ratified the treaty are at present required to: conduct inventories of the emissions of greenhouse gases from their territorial area; undertake assessments of the potential impacts of climate change; and to develop greenhouse-gas control plans. Developing countries (including South Africa) are given a grace period to achieve these goals.

This article reports the results of the first comprehensive inventory of trace gas emissions from South Africa, which was undertaken by the CSIR on behalf of the Department of Environmental Affairs and Tourism.[1]

Methodology

The guideline procedures for performing inventories are given by the Intergovernmental Panel on Climate Change.[2] In terms of the guidelines, individual nations are encouraged to use their own procedures where these are well-documented and more appropriate than the general rules the panel provides. The reference year specified by the IPCC was 1988.

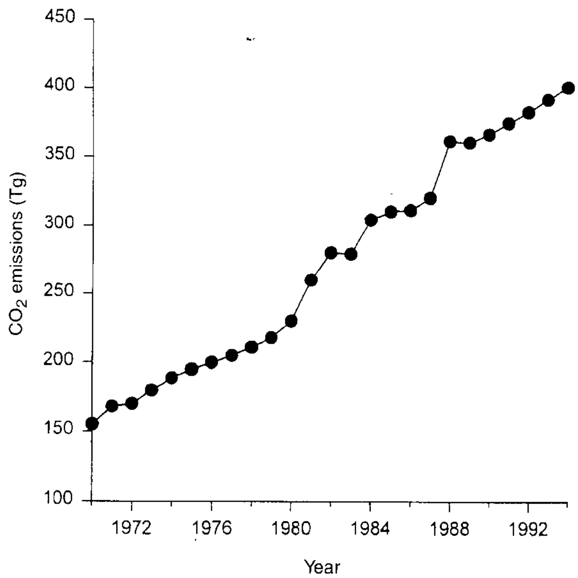

Fig. 1. Historical trend in CO_2 emissions from South Africa. In recent years these have increased by 2% annually.

Note that this preceeds the operational phase of Mossgas.*

Emissions of CO_2 are calculated by a 'top-down' approach, based on the national energy balance.[3] The energy values of the primary energy sources (oil, coal and gas) are converted to the amount of carbon that each source represents. Carbon stored in fossil-fuel based products, which are not burned and do not decay within 20 years, is deducted from the total amount of carbon present in the various primary sources. The remainder is assumed to be emitted as CO_2 within the reference year.

Other gases (CH_4, N_2O, NO_x, CO and NMVOC) are calculated by a 'bottom-up' approach based on type of activity and technology used. Emission factors for each gas (expressed as the amount emitted per unit of energy input to the process) are used to calculate the emissions of each gas from the various sources. The default emission factors given by IPCC[2] were used where South African values were not available.

The 'best estimate' (an average between the maximum and minimum values) of a gas emitted from a specific source is calculated in the case where a range of estimates exists. This is applicable to instances where different values for the amount of a greenhouse gas emitted from a specific source were quoted in the national or international literature or other methods than the IPCC[2] were used.

Chlorofluorocarbons (CFCs), although also greenhouse gases, were not included in the inventory as they are addressed in the Montreal Protocol on Substances that Deplete the Ozone Layer.

An index of South Africa's contribution to global warming is calculated by converting CH_4 and N_2O to CO_2 equivalents by using their 20-year integrated global warming potentials (64 and 270, respectively), which take into account the amount of infrared radiation they absorb and the mean lifetime of the molecules.[4] Standardized global warming potentials are not yet available for ozone precursors.

Table 1 summarizes the activities which were sources of greenhouse gas emissions in this country in 1988.[1]

Discussion and conclusions

Future research is needed to determine locally-specific emission factors for certain sources of greenhouse gases. For example, no emission factors are available for the Sasol synfuel process, which has until recently been kept secret. While these specific emission factors will refine the analysis, they will not alter the broad picture.

The single largest uncertainty in the national greenhouse gas inventory is the amount of CH_4 emitted during coal mining. Values of CH_4 emissions ranging from 0.78 to 2.07 million tons for 1988 have been estimated.[6,10,11] The main uncertainty lies in the amount of CH_4 released from the surrounding strata, and not in the *in situ* CH_4 content of the coal seam. The

* Mossgas is a multibillion rand industry based on the extraction of natural gas off the south-eastern coast of South Africa.

Table 1. Sources of greenhouse gases and amounts emitted in 1988.

Activity	CO_2 (Tg)*	CH_4 (Gg)	N_2O (Gg)	CO (Gg)	NO_X (Gg)	NMVOC (Gg)
Electricity generation[a]	153.0	1.0	1.3	23.2	695.0	
Industrial stationary combustion[b]	118.0	1.6	<0.1	82.6	702.1	
Residential/ domestic stationary combustion[c]	25.0	30.4	<0.1	1847.5	40.0	
Wood and bagasse-fired industrial processes	5.0	0.2	<0.1	92.5	6.0	
Road, air, rail and sea transport[d]	53.0	16.2	0.9	3478.8	480.0[e]	612[f]
Coal mining[g]		1425.0				
Cement and lime manufacturing	6.0[h]				23..9[i]	
Landfilling[j]		510.0				
Enteric fermentation (domestic and wild ruminants)[k]		416.0				
Decay of animal wastes[l]		166.9				
Nitrogenous fertilizers			1.0			
Termites[m]		11.8				
Cultivation of virgin grasslands	5.6[n]					
Plantations	–5.4[o]					
Non-sustainable fuelwood use[p]	3.0					
Burning of natural vegetation[q]		264.9	1.3	4651.3	30.9	
Burning of agricultural crop wastes[r]		5.4	0.1	94.5	1.9	
Total	363.2	2849.4	4.6	10270.4	1979.8	612

*1 Tg = 10^{12} g = 1 million tons; 1 Gg = 10^9 g = 1000 tons.

[a] Includes electricity generated by Eskom, Sasol and municipalities. Total energy input to electrify generation is from the addendum to ref. 3.

[b] Industrial activities include the Sasol synfuel process, coking for steel production, coal-based metallurgical processes, the coal used in the cement industry and coal- and oil-fired industrial processes. Data on the amounts of coal and oil used in these processes are from the National Energy Council report and addendum.[3]

[c] Includes open hearths, wood-, coal- and gas-fired stoves.

[d] The energy value of the amount of fuel used in 1988 was used to calculate the gas emissions. The IPCC[2] procedure specifies that aviation fuel used for airlines and shipping lines plying international routes should be excluded from the national use as it will be calculated on a global scale. It is currently not possible to separate the domestic and international use of aviation fuel in South Africa.

[e] Estimates have been made for South Africa based on the assumption that South African vehicles emit 75% of the European legal limit .[5]

[f] Mobile combustion is the major source of NMVOC but not the only source as stipulated in the IPCC[2] guidelines. Vegetation fires and the direct emission of substances such as isoprene and monoterpenes from tree leaves are two natural sources of NMVOC. Since these two sources are not known to have been altered by human activity, they were not included in the IPCC methodology.

[g] Coal mining and the subsequent handling contributed more than 50% of the total amount of CH_4 emitted from SA territory. Of the three types of mining methods (surface, pillar and longwall) used in South Africa, pillar mining has the highest emission factor (16 m^3 CH_4/Mg coal mined) compared to 10.2 m^3 CH_4/Mg coal mined for the two others based on OECD methodology.[6] The validity of these emission factors under South African conditions is a significant source of uncertainty.

[h] These emissions result from the conversion of calcium carbonate to cement. The CO_2 emissions resulting from the energy needed to drive the lime and cement manufacturing processes are excluded as they are accounted for under the energy section.

[i] IPCC does not include emission factors for gases other than CO_2. Data were provided by the SA Cement Producers Association.[7]

[j] CH_4 is extracted from landfill sites for use as a fuel on an experimental basis, but the fraction captured is presently very small. Extraction began only after 1988.

[k] The mean number of livestock has been fairly stable for several decades although there are fluctuations in the annual numbers, generally related to periods of drought.[8] Most of the livestock in SA feed off natural, rain-fed rangelands, usually of low quality and productivity, leading to high CH_4 emissions per head.

[l] The volatile solids (VS) in the waste stream from the various sources are calculated and emission potential factors are then applied to the VS content. Different waste disposal methods determine the actual amount of CH_4 emitted. Most of the animal waste in SA is directly deposited onto the rangeland where the animals feed. Little CH_4 is produced because the dung dries out very rapidly.

[m] Termites are common in SA, especially in the warm, arid parts. It has been assumed that termites produce about 0.06 mg $CH_4 m^{-2} y^{-1}$ for each g of organic matter consumed.[1]

[n] The static procedure for calculating CO_2 emissions from land-use change as given in the IPCC[2] was inappropriate for SA due to the low net present conversion between grasslands and croplands. A dynamic method was used instead, which takes into account the residual effects of extensive conversions which took place in the sixties and seventies.

[o] The amount of CO_2 uptake by plantations is calculated by the amount of carbon sequestered in wood products (saw logs, mining timber and paper).

[p] Fuelwood forms the basis of the domestic energy economy of about half of all South Africans. Nearly 11 million tons of wood is burned annually. Where this wood is sustainably harvested (i.e. less is removed than grows) there are no net carbon emissions. It has been assumed that 25% of fuelwood use is unsustainable.[9]

[q] Fire plays an important role in the management of the savannas, grasslands and fynbos vegetation types in SA. About 17% of the total area of fynbos, savanna and grasslands (792 713 km^2) is burned annually. This is not a net source of CO_2, but is a net source of trace gases not taken up in the subsequent regrowth.

[r] Sugar cane is the only crop burned in SA as part of a widespread management practice.

equations supplied by IPCC[2] may not be applicable to South Africa, and research should focus to improve them for local conditions. Mine-by-mine and basin-specific approaches for subsurface and surface mines, respectively, will be required to estimate the CH_4 emissions from coal mining reliably.

The main sources of greenhouse gas emissions in South Africa relate to the mining and combustion of coal. These activities generate more than 80% (426 million tons of CO_2 equivalent) of the total output of these gases from South African territory.

The historical trend of CO_2 emissions from this country (1970–1994) is shown in Fig. 1. These emissions have increased on average by 2% per year for the last six years. It is predicted that South Africa's CO_2 emissions will increase by 3% annually for the next 20 years unless action is taken to moderate them.[12] This projected increase is based on a scenario which assumes that the reduction of greenhouse gases is not a primary consideration in development plans. Coal mining, electricity generation, mobile fuel use, the municipal waste stream and household fuel use are predicted to increase by at least 3% per year per sector for the next 20 years.[12] These growth rates are driven mainly by population and economic growth and urbanization.

The high growth rate of CO_2 generation will certainly place South Africa in conflict with the FCCC. The most cost-effective options for this country to control and reduce its greenhouse gas emissions in the future could be:

- to use energy more efficiently in the domestic and industrial sectors;
- to harvest CH_4 from municipal solid waste and coalbeds; and
- to improve animal management.

There is a limited potential for CO_2 uptake by forests in South Africa for the following reasons:

- the adverse environmental impacts (such as loss of biodiversity) of further afforestation;
- the negative influence of plantation forestry on the water supply; and
- the limited area available that is bioclimatically suitable for afforestation.

In 1990 carbon storage in forest products and in new afforestation amounted to 13.5 Tg of CO_2 or approximately 3.8% of the total CO_2 emissions from South Africa. This figure differs from the one quoted in Table 1 for the following reasons: different years were used (1988 and 1990); and the amount of accumulated biomass and timber products.

Although not insignificant, this amount of carbon sequestered is too small to reduce the national emission budget drastically. It could be possible, however, to increase the carbon storage in natural woodlands by reducing the frequency of veld fires and managing the woodlands for sustainable harvest.[13]

Although South Africa contributes only about 1.2% to the additional radiation load on the global atmosphere, this value is disproportionately high relative to the national fraction of the global economy and population. South Africa ranks among the top 10 and 20 countries in the world, respectively, regarding the tons of C emitted per unit of gross domestic product annually and tons of C emitted per capita per year.[14]

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Productivity report records a dismal performance

Employment in the formal sector of the South African economy has been stagnant for a generation. This sector now employs the same number of people as in 1980, and the number of black people at work in local factories is the same as it was in 1975. This is the grim message of Jan Visser, executive director of the National Productivity Institute, writing in the institute's latest annual report.

He goes on: 'The gross domestic production per capita decreased at a rate of two per cent per annum since 1980. Since the production per capita in a country equals the consumption per capita, this means that poverty increased at a rate of two per cent per year over the past fifteen years. This is not the kind of soil in which any country can hope to grow a flourishing democracy. It is not soil, it is sand, and it is fast running out.'

While the plight of the growing unemployed is bad enough, and threatens the welfare of all, the fate of those at work has been 'pathetic' overall. Visser writes: 'Although the nominal earnings per employee increased at a rate of 15.4 per cent per year from 1981 to 1994, the real earnings per employee increased at a rate of only one per cent per year. If this is not a pathetic performance, I do not know what is.' □

3RD INTERNATIONAL CONFERENCE OF THE SOCIETY OF NEUROSCIENTISTS OF AFRICA

The 3rd International Conference of the Society of Neuroscientists of Africa will be held in Cape Town, from 21 - 25 April 1997. The accent will be on disorders of the nervous system but attention will also be given to basic neuroscience topics such as molecular determinants of nervous system development, neuronal cytoskeleton, extracellular matrix, sensory neurobiology of African fauna, computational neuroscience and neuroendocrine and autonomic regulation. Workshops will provide instruction in basic communication skills, functional, chemical and molecular neuroanatomy, and behavioural neuroanatomy. For further information, please contact: Dr Vivienne Russell, P.O. Box 19113, 7505 Tygerberg; tel. +27 21 938-4170; fax +27 21 931-7810.