Information on climate change in South Africa:
greenhouse gas emissions and mitigation options

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TOPIC 3

Carbon accounting for South Africa

Contents

1. IPCC standard emission factors

Table 1: IPCC default carbon contents (IPCC 2007)

Fuel type English description	Default carbon content [1] (kg/GJ)	Lower	Upper
Crude Oil	20.0	19.4	20.6
Orimulsion	21.0	18.9	23.3
Natural Gas Liquids	17.5	15.9	19.2
Motor Gasoline	18.9	18.4	19.9
Aviation Gasoline	19.1	18.4	19.9
Jet Gasoline	19.1	18.4	19.9
Jet Kerosene	19.5	19	20.3
Other Kerosene	19.6	19.3	20.1
Shale Oil	20.0	18.5	21.6
Gas/Diesel Oil	20.2	19.8	20.4
Residual Fuel Oil	21.1	20.6	21.5
Liquefied Petroleum Gases	17.2	16.8	17.9
Ethane	16.8	15.4	18.7
Naphtha	20.0	18.9	20.8
Bitumen	22.0	19.9	24.5
Lubricants	20.0	19.6	20.5
Petroleum Coke	26.6	22.6	31.3
Refinery Feedstocks	20.0	18.8	20.9
Refinery Gas [2]	15.7	13.3	19.0
Paraffin Waxes	20.0	19.7	20.3
White Spirit & SBP	20.0	19.7	20.3
Other Petroleum Products	20.0	19.7	20.3
Anthracite	26.8	25.8	27.5
Coking Coal	25.8	23.8	27.6
Other Bituminous Coal	25.8	24.4	27.2
Sub-Bituminous Coal	26.2	25.3	27.3
Lignite	27.6	24.8	31.3
Oil Shale and Tar Sands	29.1	24.6	34
Brown Coal Briquettes	26.6	23.8	29.6
Patent Fuel	26.6	23.8	29.6
Coke Oven Coke and Lignite Coke	29.2	26.1	32.4
Gas Coke	29.2	26.1	32.4
Coal Tar [3]	22.0	18.6	26.0
Gas Works Gas [4]	12.1	10.3	15.0
Coke Oven Gas [5]	12.1	10.3	15.0
Blast Furnace Gas [6]	70.8	59.7	84.0
Oxygen Steel Furnace Gas [7]	49.6	39.5	55.0
Natural Gas	15.3	14.8	15.9

Fuel type English description	Default carbon content [1] (kg/GJ)	Lower	Upper
Municipal Wastes (non-biomass fraction)[8]	25.0	20.0	33.0
Industrial Wastes	39.0	30.0	50.0
Waste Oils [9]	20.0	19.7	20.3
Peat	28.9	28.4	29.5
Wood/Wood Waste [10]	30.5	25.9	36.0
Sulphite lyes (black liquor) [11]	26.0	22.0	30.0
Other Primary Solid Biomass [12]	27.3	23.1	32.0
Charcoal [13]	30.5	25.9	36.0
Biogasoline [14]	19.3	16.3	23.0
Biodiesels [15]	19.3	16.3	23.0
Other Liquid Biofuels [16]	21.7	18.3	26.0
Landfill Gas [17]	14.9	12.6	18.0
Sludge Gas [18]	14.9	12.6	18.0
Other Biogas [19]	14.9	12.6	18.0
Municipal Wastes (biomass fraction) [20]	27.3	23.1	32.0

Notes:

[1] The lower and upper limits of the 95 percent confidence intervals, assuming lognormal distributions, fitted to a dataset, based on national inventory reports, IEA data and available national data. A more detailed description is given in section 1.5

[2] Japanese data; uncertainty range: expert judgement;

[3] EFDB; uncertainty range: expert judgement

[4] Coke Oven Gas; uncertainty range: expert judgement

[5] Japan & UK small number data; uncertainty range: expert judgement

[6] 7. Japan & UK small number data; uncertainty range: expert judgement

[8] Solid Biomass; uncertainty range: expert judgement

[9] Lubricants ; uncertainty range: expert judgement

[10] EFDB; uncertainty range: expert judgement

[11] Japanese data; uncertainty range: expert judgement

[12] Solid Biomass; uncertainty range: expert judgement

[13] EFDB; uncertainty range: expert judgement

[14] Ethanol theoretical number; uncertainty range: expert judgement

[15] Ethanol theoretical number; uncertainty range: expert judgement

[16] Liquid Biomass; uncertainty range: expert judgement

[17-19] Methane theoretical number; uncertainty range: expert judgement

[20] Solid Biomass; uncertainty range: expert judgement

2. Carbon accounting

2.1 Life cycle emission estimates for South Africa's electricity and liquid fuels

2.1.1 Electricity generation

Table 2 presents the carbon dioxide emission factor specific to South Africa's Eskom electricity generation, transmission and distribution. The emission factor is based on a study of three of the country's base-load coal-fired power stations (Kendal, Lethabo and Arnot) by a team of engineers and scientists between 2002 and 2005. The study experimentally determined emission factors for underground coal mining, power plant CO_2 and NO. It was assumed that the emissions from the three power stations analysed are representative of the emissions in all coal-fired power stations in South Africa. Fractions of electricity generated from the different energy sources were estimated from average electricity generated by different Eskom technologies between 2002 and 2004.

Table 2: Emission factor for Eskom-generated electricity in kg CO_2-eqt per kWh

	Value	*Units per kWh electricity*	*Reference*
% electricity generated from coal	92.0		Eskom (2007)
% electricity generated from gas (kerosene)	0.0000836		Eskom (2007)
% electricity without carbon emissions	8.0		Eskom (2007)
Total emissions from coal-fired plants	0.993	kg CO_2-eqt	
CO_2 emissions from coal power plants	0.978	kg CO_2	Zhou, Yamba et al. (unknown)
N_2O-eqt emissions from coal mining NO_x	0.000038	kg N_2O-eqt	Zhou, Yamba et al. (unknown)
CH_4 emissions from coal mining	0.000178	kg CH_4	Zhou, Yamba et al. (unknown)
CO_2 emissions from kerosene plants	0.955	kg CO_2	Eskom (2007)
Overall power plant emissions	*0.914*	*Kg CO_2-eqt*	
Transmission losses	8.33	%	Eskom (2007)
Distribution losses	1.74	%	Eskom (2007)
Eskom average Emission Factor	1.015	kg CO_2-eqt/kWh	

2.1.2 Liquid fuels

In this section, life-cycle GHG emissions for the liquid fuels sector have been detailed. These emissions have been divided into three categories, based on the primary energy source: crude oil, coal and natural gas.

2.1.2.1 Liquid fuels from crude oil

Assumptions

- Key life cycle steps that have been included in determining GHGs emissions emitted from crude oil-based liquid fuels are:

- crude oil production[1] (including drilling and pre-processing);
- pipeline transport from the oil rig to onshore facilities;
- tanker transport to South African ports;
- liquid fuels production at South African crude oil refineries (Calref, Enref, Natref and Sapref);
- complete combustion of liquid fuels by end-users.

- Liquid fuels transport and distribution emissions have not been explicitly determined. However, these emissions are expected to be embodied in emissions from complete combustion of the fuels.
- Fugitive emissions from pipeline transport of crude oil to inland refineries have not been included.

Liquid fuels production

Table 3 shows carbon dioxide emission equivalents for the production of liquid fuels in South African refineries, using a base year of 1997.

Table 3: GHGs emissions from crude oil-based liquid fuels production in South African refineries (kton CO_2-equiv; base year: 1997; adapted from Frischknecht & Jungbluth (2007))

	Calref	*Enref*	*Natref*	*Sapref*
LPG	40.6	42.3	6.8	120.2
Petrol	958.9	975.3	1021.5	1656.1
Kerosene	338.5	261.3	570.5	515.1
Diesel	866.7	762.0	934.5	1538.9
Heavy fuel oil	579.2	679.3	104.9	1284.1
Refinery gas	0.0	9.1	0.0	23.1
Totals	**2784.0**	**2729.3**	**2638.2**	**5137.5**

Relative contributions of each fuel product to GHG emissions by refinery facility are shown in Figure 1.

[1] It has been assumed that South African crude oil refineries use Middle Eastern (Iranian) crude as their primary feedstock.

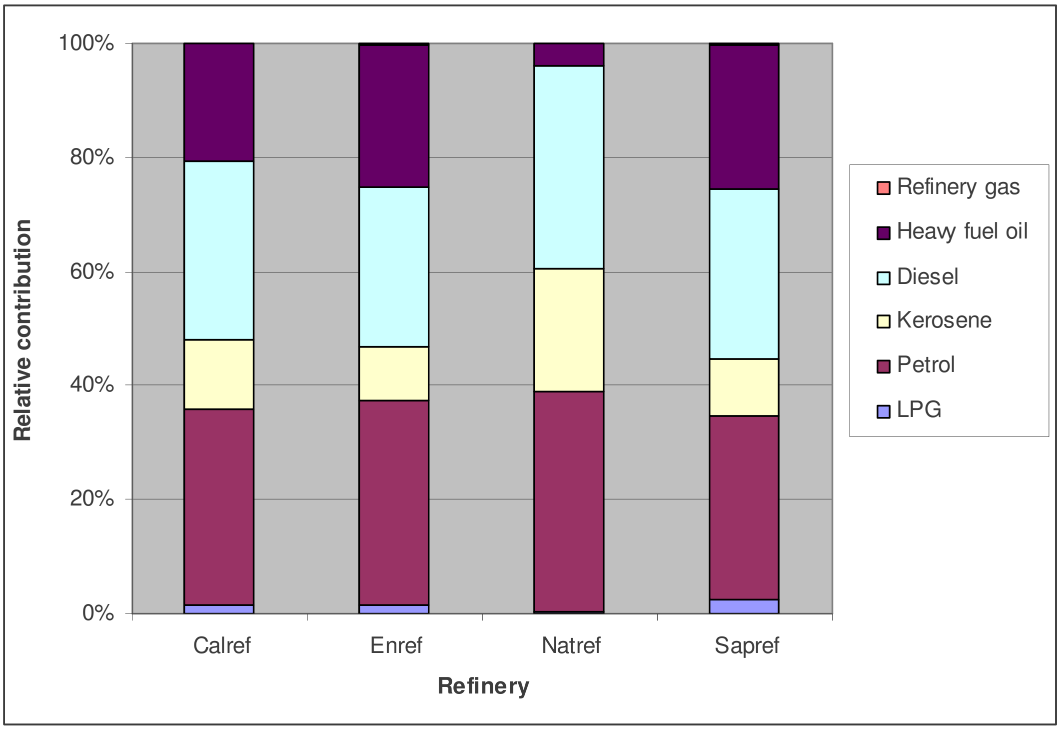

Figure 19: Relative contributions of liquid fuel products to GHGs emissions for South African refineries

End-use combustion

Table 4 below shows carbon dioxide emission equivalents for the consumption of liquid fuels in South African refineries, using a base year of 1997.

Table 4: GHGs emissions from crude oil-based liquid fuels combustion by source (kton CO_2-eq; Base year: 1997)

	Calref	*Enref*	*Natref*	*Sapref*
LPG	0.13	0.16	0.46	0.03
Petrol	0.00	0.03	0.08	0.00
Kerosene	3.50	3.56	6.05	3.73
Diesel	1.55	1.20	2.36	2.61
Heavy fuel oil	4.04	3.55	7.17	4.35
Refinery gas	2.85	3.35	6.33	0.52
Totals	**12.1**	**11.8**	**22.4**	**11.2**

The overall relative contribution of South African crude oil refineries to total GHG emissions from liquid fuels is shown in Figure 2.

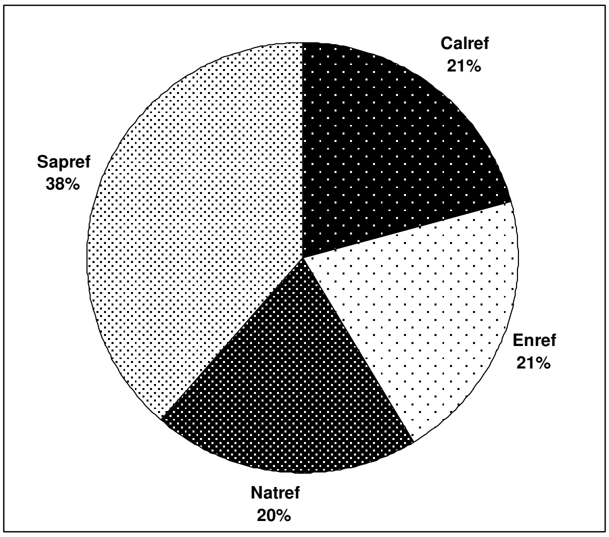

Figure 2: Relative contribution of South African refineries to total country greenhouse gas emissions from crude oil-based liquid fuels production and combustion

2.1.2.2 Liquid fuels from coal

Liquid fuel products in South Africa can be derived from coal using the Fischer-Tropsch process. Sasol is the only significant producing company that utilises this technology in the country. GHGs emissions arising from this production process have thus been included here.

Assumptions

- The Secunda complex is the only production facility using coal as the primary feedstock for the process (the Sasolburg complex, Sasol One, has been using Mozambiquan pipeline natural gas since 2004)
- Fischer-Tropsch products in the Secunda complex are derived from high-temperature Fischer-Tropsch conversion, which favours the formation of light hydrocarbons such as petrol and fuel alcohols (Sasolburg uses a low-temperature Fischer-Tropsch conversion, which has high yields for long-chain hydrocarbons such as waxes and paraffins).
- Fischer-Tropsch products are co-generated with electricity as a process by-product
- Daily GHG emissions were determined from a carbon balance over the process. This carbon balance is shown in Table 5 below.

Table 5: Carbon balance for the production of liquid fuels from coal (Base year: 2003; Adapted from Steynberg & Nel (2004))

Inputs (tons/day)	
Coal	34 782.3
Total	34 782.3
Outputs (tons/day)	
Fischer-Tropsch products	10 967.5
CO_2 removal	18 615.9
Slag	180.8
Sulphur plant flue gas	649.3
Power plant flue gas	4 368.8
Total	**34 782.3**

Table 6 below shows carbon dioxide emission equivalents for the production and complete combustion of liquid fuels from South African coal, using a base year of 2003.

Table 6: Annual carbon dioxide emissions from coal-based production and consumption of Fischer-tropsch fuels in South Africa (Base year: 2003)

	Mtons/annum
Fischer-Tropsch products	13.3
CO_2 removal	22.5
Slag	0.22
Sulphur plant flue gas	0.79
Power plant flue gas	5.28
Total	**42.06**

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