Research brief
Tier 2 greenhouse gas emission factors for South African liquid and gaseous fuels

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The South African Greenhouse Gas reporting regulations (DEA 2017a) require that certain emission categories (including gaseous and liquid fuels for transport and stationary applications) use tier 2 methods to report greenhouse gas emissions starting five years after April 2017. Higher tier methods for greenhouse gas reporting require country-specific emission factors.

This brief reports on the results obtained from sampling and analysing petrol (ULP93 and ULP95), diesel, jet kerosene (also known as Jet A1), aviation gasoline, paraffin, and residual fuel oil (also known as heavy fuel oil). Country-specific emission factors were also determined for liquified petroleum gas (LPG), using appropriate empirical calculations representative of the South African market.

Samples of selected liquid fuels used in South Africa were collected over the summer and winter seasons of 2021 in the Gauteng, Mpumalanga, Free State, KwaZulu-Natal and Western Cape Provinces, primarily from large retail stations along major traffic routes (unleaded petrol ULP93 and ULP95 and diesel). Liquid fuels used in smaller volumes (bio-ethanol, paraffin, jet kerosene, aviation gasoline and heavy fuel oil) were also sampled at appropriate locations. Sampling of liquid fuels was conducted according to a standard operating procedure (SOP) developed for the project, based on EN 1475:2013 (CEN 2013).

All samples (343 in total) were analysed at the accredited SGS South Africa (Pty) Ltd Oil, Gas and Chemicals Division Laboratory in Durban. Determination of total carbon (TC) was performed using an SGS in-house method (NDIR-1) based on ASTM D5291 and ASTM D7662 (ASTM 2016, ASTM 2020). This method employs an elemental analyser based on nondispersive infrared (NDIR) spectroscopy. The calorific value of 199 fuel samples was also determined by method ASTM D4868 (ASTM 2010) to allow for the calculation of methane and nitrous oxide emission factors. Results were statistically analysed using method API 2572 (API 2013) to determine mean values and their uncertainties, identify outliers and determine correlations between variables. Results for ULP93 and ULP95 were weighted by their respective 2021 annual average sales volumes to obtain an average value for all types of petrol. Based on sales data from the years 2018-2021, summer and winter results were equally weighted to obtain annual average emission factors for ULP93, ULP95 and diesel, reflecting a slight decrease from the values contained in the Technical Guidelines for Monitoring, Reporting and Verification of Greenhouse Gas Emissions by Industry until recently being used by DFFE (DEA 2017b). A calculation-based liquefied petroleum gas emission factor, confirmed by analysis certificates from a few local suppliers, was found to be 3002 g CO_2/kg. For heavy fuel oil (HFO), the carbon content was found to be 85.93±1.58% and the density 0.994±0.12 g/l. The latter figure must be treated with some caution, as the fuel market conditions at the time of sampling required imports of HFO to be made, which is not normally the case.

Full results are given in tables 1 and 2 below. Detail of the methods used and of the correlation between variables studied are given in Kornelius et al (2022), while the Department of Forestry, Fisheries and the Environment has published the Methodological Guidelines for the Quantification of Greenhouse Gas Emissions providing information on the application of the results of the study (DFFE 2022).

Table 1: *National emission factors for carbon dioxide compared to the Technical Guideline values*

Fuel Type	National CO_2 Emissions Average (g/L), this study	Technical Guideline (DEA 2017b) (g/L)
Aviation gasoline	2229	2202
Jet kerosene	2528	2491
Diesel	2650	2692
Bioethanol	1470	Note 1
Residual fuel oil (HFO)	3124	2996
Paraffin	2424	2488
Petrol	2263	2302

Note 1: The Technical Guideline does not provide a value for bioethanol.

Table 2: *Carbon content, density and calorific value of liquid and gaseous fuels. 5% and 95% confidence intervals given*

	Fuel Type						
	Jet kerosene	Aviation gasoline	Diesel	Bioethanol	Paraffin	ULP93	ULP95
National Carbon Content Summer (g/L)	700.0±12		729.3±2.8			620.7±3.6	621.4±4.0
National Carbon Content Winter (g/L)	675.5±11	608.2±6.8	717.3±3.5	401.8±1.7	661.6±17	610.1±10	613.6±3.6

	Fuel Type						
	Jet kerosene	Aviation gasoline	Diesel	Bioethanol	Paraffin	ULP93	ULP95
National Carbon Content Summer (%)	87.97±0.99		88.31±0.79			84.13±1.3	83.60±0.47
National Carbon Content Winter (%)	85.42±1.0	85.08±0.84	87.00±0.38	49.88±0.25	86.48±0.67	82.66±0.44	82.68±0.33

	Fuel Type						
	Jet kerosene	Aviation gasoline	Diesel	Bioethanol	Paraffin	ULP93	ULP95
National Density Summer (kg/L)	0.797±0.006		0.826±0.002			0.738±0.002	0.743±0.002
National Density Winter (kg/L)	0.791±0.006	0.714±0.001	0.825±0.002	0.805±0.0001	0.765±0.02	0.739±0.003	0.742±0.002

	Fuel Type		
	Diesel	ULP93	ULP95
National CV (higher) Summer (MJ/kg)	45.93±0.09	46.94±0.23	46.97±0.10
National CV (lower) Summer (MJ/kg)	43.05±0.07	43.83±0.18	43.85±0.08

	Fuel Type		
	Diesel	ULP93	ULP95
National CV (higher) Winter (MJ/kg	45.85±0.043	47.08±0.085	47.00±0.028
National CV (lower) Winter (MJ/kg)	42.99±0.033	43.94±0.066	43.87±0.021

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