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Assessment of Greenhouse Gas Emissions in Cameroon's Road Transport Sector

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Abstract:
The increase in the number of vehicles has resulted in a continuous growth in the consumption of fuel in Cameroon; and has contributed to the increase of Cameroon's GHG emissions. GHG emissions inventory from the road transport sector during the period 1995-2008 reported in this paper was conducted following the recommendations of the UNFCCC. The study also includes the indicators that are the major contributors to Cameroon's GHG emissions. The direct GHG emissions are calculated on a bottom-up Tier 2 methodology described by the IPCC guidelines and Kaya's approach, except for CH_4 and N_2O, CO_2 emission factors which are specific to Cameroon. Assessment results show that GHG emissions have increased by 50.50% during the period 1995-2008. Cameroon's road transport sector emits into the atmosphere an average of 1421.4 kilotons of CO_2 equivalent per year, 852.5 (59.98%) and 568.9 (40.02%) kilotons of CO_2 equivalent per year for gasoline and diesel vehicles respectively. CO_2 emissions in the road transport sector represent 34.33% of the total CO_2 emissions in Cameroon due to the energy sector. The results suggest future policy implementation to support sustainable alternative fuel and equally the deployment of low-carbon technology for vehicles, rejuvenation of Cameroon's vehicle fleet, improve road traffic and encourage public transport.

Keywords: Assessment, Cameroon, Fuel consumption, GHG emissions, Road transport.

1.0 Introduction:
The United Nations Commission for the Environment has clearly demonstrated the degradation of the environment both globally and regionally in conjunction with economic activity. This awareness grew stronger at the Rio Summit (Brazil) in 1992 through the acceptance of the concept of Sustainable Development by the entire international community.

After the Rio Summit, Cameroon became a member of the United Nations Framework Convention on Climate Change (UNFCCC) in 1994. Thus, Cameroon is committed with the international community to help stabilize concentrations of greenhouse gases (GHGs) in the atmosphere to an extent that would prevent dangerous interference of human activities with the climate system. The Cameroonian government has managed to realise in 1995 inventories of greenhouse gas (GHG) in the energy, industrial, agricultural, land use and waste sectors (Ministry of Environment and Forests, MoEF, 2005). In 1997, a new financial assistance from the Global Environment Facility enabled Cameroon to prepare its first National Communication by developing inventories of greenhouse gas emissions, with 1994 as a base year. Thus, a first National Communication on the GHG inventory in Cameroon was issued to the UNFCCC in 2005, with 1994 as the reference and only year of study (MoEF, 2005). In order to improve its performance and honor its commitment, the Cameroon second National Communication to the UNFCCC is in preparation.

GHG emissions in the energy sector in Cameroon are certainly not as high as those in developed countries. The work of the Cameroon government on the first National Communication of GHG inventories in the energy sector were made following the Tier 1 approach (IPCC, 1997) in the following emission sectors: transports, energy industries, manufacturing and construction and the residential sectors. Cameroon government used the default emission factors of the Intergovernmental Panel on Climate Change (IPCC) for a National Communication on the GHG inventory to the UNFCCC. The result of this work showed that the contribution from the combustion of fossil fuel for CO_2 emissions in the atmosphere in Cameroon was estimated at 2216.07 kilotons (kt) in the year 1994 (MoEF, 2005). Transport was responsible for 61% of these emissions against 17% for the residential sector, 11% for manufacturing and construction in 1994. The part of the energy industries was 9% and 2% for other sectors. The amount of CO_2 emitted by road transport was 1169.45 kt, 86% of emissions from the transport sector and 53% of emissions from the energy sector (MoEF, 2005). According to the world data bank (World Bank, 2012), the total CO_2 emissions in Cameroon due to the energy sector were estimated in 1994 to be 3817 kt. This shows that, CO_2 emitted by the road transport sector according to the National Communication represents 31% of the total CO_2 emissions.

However, the road transport category in particular has not been examined in detail. Thus, to contribute to the work of the Cameroon government on the assessment of GHG emissions, the authors, through this article estimates GHG emissions in Cameroon's road transport sector during the period 1995-2008. This is because 1995-2008 corresponds to the period when statistical data were reliable. According to the guidelines of the IPCC (2006) and IPCC recommendations on good practice (2000), the methodology used to estimate road transportation GHG emissions follows a bottom-up Tier 2 method. This method starts from final fuel consumption to calculate the CO_2 emissions by each sector. In addition, the authors take into account the indicators (fuel consumption, economic growth, population and vehicle fleet) that are the major contributors to GHG emissions in Cameroon's road transport sector. Thus, to the first method, we add Kaya's method (Kaya and Yocobori, 1997) or a modified form of Kaya's method.

Emissions from the road transport sector, classified by the IPCC (2006) code 1A3b cover all combustion and evaporative emissions arising from fuel consumption used in road vehicles, including the use of agricultural vehicles on paved roads. GHG emissions in Cameroon's road transport include three direct GHGs (CO_2, CH_4 and N_2O) in kilotons of CO_2 equivalent (kt CO_2-eq). The CO_2 emission factors are specific to Cameroon and were evaluated experimentally in the laboratory of the Cameroon's refinery (SONARA's laboratory) in 2010, using the American Society of Testing Materials standards (ASTM Standards, 2010). The emission factors of CH_4 and N_2O are those recommended by the IPCC (2006) for countries that do not have the necessary technology and equipment suitable for the calculation of these emission factors.

This study presents a double objective. Firstly, the method used in this study would contribute to improve on the second National Communication of GHG emissions inventories of Cameroon to the UNFCCC. Secondly, the results in this study will permit future policies to put in place mechanisms in order to reduce GHG emissions in the road transport sector in Cameroon. The structure of this paper is as follows: in the next section, we present the overview of indicators that contribute to GHG emissions in Cameroon's road transport sector. In Section 3, the methodology and data adopted in the study are presented. Section 4 presents results and discussion, and the last section concludes the study.

2.0 Overview of indicators:

2.1 Population and Gross Domestic Product:

Cameroon (SIE-Cameroun, 2009; Ecof, 2007; Moutou, 2002) has made three population censuses. The first, second and third population census were made in the years 1976, 1987 and 2005 respectively. Cameroon's population was assessed as 7663246; 10493655 and 17463836 inhabitants respectively (Bucrep, 2010; Nkué and Njomo, 2009). In 2006, the population of Cameroon was estimated to be 17.5 million inhabitants by the Statistical Yearbook of Cameroon. The third Cameroon Household Survey (Ecam 3, 2008) established in 2008 estimated the population of Cameroon to be 17.9 million inhabitants in the year 2007. Similarly, the SIE-Cameroon (2009) estimate for 2008 was 18.4 million with an annual growth rate averaging 2.54% between 1995 and 2008.

Cameroon's Gross Domestic Product (GDP) is taken as a proxy for economic growth. The wealth of Cameroon is shown by its GDP, and its economy is largely based on various agricultural products and the petroleum sector. Moreover, GDP (constant

2000 US dollars) was estimated at 13.29 billion US dollars in 2008 (World Bank, 2011). Since 1995, Cameroon returned to a positive GDP growth thanks to the economic policies on Structural Adjustment and the devaluation of the CFA franc in January 1994. The average growth rate of GDP was 4.01% per annum during the period 1995-2008. The Cameroonian economy has resumed growth that could be described as positive from 1995, announcing the release of the long economic crisis of 1987 to 1997 experienced by Cameroon. However, the average growth rate of GDP annually is well below the minimum of 6% recommended by the Growth and Employment Strategy Paper (GESP, 2005) to attain the Millennium Development Goals (MDGs).

2.2 Road Transport and Vehicle Fleet:

Road transport is the main transportation mode in Cameroon for both passengers and goods. It provides nearly 90% and 75% of domestic transport demand for passengers and goods (SIE-Cameroun, 2009). In contrast to rail, air and sea transports (which have a limited use due to geographical and economic constraints), road transport has the advantage of being able to access almost everywhere in the country.

According to the Highway Department of the Cameroon's Ministry of Public Works (Ministry of Public Works, 2008), road transport is the most used transport in Cameroon. The national road network in 2007 extended over 53000 km, of which approximately 9% are urban roads and 91% are rural roads. Figure 1 shows the map of Cameroon's road transport (roads are represented by brown lines).

Fig. 1: Map of Cameroon's road transport

According to the Cameroon's Ministry of Transport (2008), the vehicle fleet (except motorcycles) is old (average 30 years) with over 70% of used and non-controlled vehicles. The Environmental Energy Technologies Laboratory (EETL) of the University of Yaounde I studies showed that the average annual growth rate of vehicle fleet was 5.33% from 1995 to 2008. The vehicle fleet varied from 174388 vehicles in 1995 to 351249 vehicles in 2008, that is an increase of 101.42%. Note that this increase is mainly made up of used and non-controlled vehicles. The national vehicle fleet has operated with an average of 61% as gasoline vehicles and 39% as diesel vehicles from 1995 to 2008.

2.3 Fuel consumption in Cameroon's road transport sector:

In terms of road infrastructure, the transport sector in Cameroon has experienced the most remarkable developments in recent years. This road development has increased the gasoline and diesel energy consumption in the road transport in Cameroon. The Energy Information System of Cameroon (SIE-Cameroon, 2009) is ranked second with 12.2% of total final energy consumption in 2008, after the residential sector with 74% (94% of final energy consumption in the residential sector in 2008 is biomass and 6% of modern energy) and before the industrial sector with 6%. The small percentage of the industrial sector reflects the low level of economic and industrial development in Cameroon. The transport sector is the first consumer of petroleum products in Cameroon. Road transport consumes almost all of this energy; about 95% of the energy is intended for the transport sector.

The transport fuel, as well as domestic gas are subsidized by the government of Cameroon (Bwemba, 2008). However, their prices vary according to the international price of Brent. Despite efforts to stabilize prices by the government of Cameroon through the Hydrocarbons Prices Stabilization Fund (HPSF, 2009), they still continue to rise. Fuel prices at the pump of gasoline and diesel respectively rose from 0.64 and 0.47 US dollars per litre in 1995 to 1.33 and 1.22 US dollars per litre in 2008. This is an increase of about 108% for gasoline and 160% for diesel. In 14 years, we find that the price of diesel has more than doubled and approached increasingly that of gasoline. The rise in prices at the pump creates a very important difference compared to prices in Nigeria, first African oil producer with whom Cameroon shares over 1700 km border (Nkué and Njomo, 2009).

Gasoline and diesel were supplied throughout the territory by 426 service stations in 2008. They belonged to the marketers and the distribution is still dominated by Total (SIE-Cameroun, 2010). The service stations covered about 96% of the fuel distribution throughout the territory in 2008.

Road transport fuel consumption in Cameroon increased from 348 ktoe in 1995 to 522 ktoe in 2008, a growth of 49.92% and at an average growth rate of 3.16% per annum (HPSF, 2009). Overall, Cameroon's road transport consumed about two tonnes of oil equivalent (toe) per vehicle in 1995 and 1.49 toe per vehicle in 2008 averagely. Therefore, the Cameroon's road transport consumption per vehicle shows a decrease. According to the calculations of the EETL, the proportion of diesel consumption in road transport between 1995 and 2008 had significantly increased while that of gasoline had decreased. In 1995, the share of consumption of diesel to that of fuel consumption was 28.69% and increased to 40.22% in 2008. Despite this increase in consumption of diesel, gasoline was still the most widely used fuel in Cameroon road transport, thus having a 59.78% share of consumption in 2008 (HPSF, 2009).

Population and economic growth have resulted in a continuous growth of vehicle fleet (gasoline and diesel vehicles). Similarly, the increased number of gasoline and diesel vehicles resulted in a continuous growth in Cameroon's fuel consumption, which has been widely accepted as a major contributor to Cameroon's GHG emission increase. Consequently, population, GDP, vehicle fleet and fuel consumption are accepted as the indicators and the contributors to Cameroon's GHG emissions increase in road transport.

3.0 Methodology and data:

In the Guidelines and the Good Practice Guidance of IPCC (IPCC, 2006, 2000), the bottom-up Tier 2 method is used to estimate GHG emissions from fuel combustion based on the country-specific emission factors and on the quantity of fuel consumed at the source category level. In general, for each source sector or category, GHG emissions are calculated when the quantity of fuel consumed at the national level of detail is multiplied by a specific emission factor. This is illustrated by the following expression:

$$E = FC_f \times EF_{g,f,T} \quad (1)$$

where E is GHG emissions by source category in kt CO_2-eq, FC_f is the quantity of fuel consumed (in physical units, such as kg, l, or m^3) by fuel type *(f)*, $EF_{g,f,T}$ is the country-specific emission factor (in physical units) by gas *(g)* and by fuel type *(f)* and by technology *(T)* (for non-CO_2 factors).

3.1 Calculations:

Shabbir and Ahmad (2010) showed that, the total travel demand in the road transport sector was estimated as follows:

$$Travel\ demand(t) = \sum Vi(t) \times VKTi(t) \times vehicle\ occupancy\ rate(t) \quad (2)$$

where V*i(t)* is the number of fuel vehicles on the vehicle fleet, VKT*i(t)* is the average annual vehicle-kilometer travelled by a vehicle fleet of fuel type *i* in year *t*. The fuel consumption of the vehicles by fuel types are formulated as a function of the travel demand and AF*(t)* is the average number of kilometer travelled for a vehicle per litre of fuel consumed each year Therefore, fuel consumption of vehicles can be calculated by the following equation:

$$FC(t) = Travel\ demand(t) \times AF(t) \quad (3)$$

3.1.1 Fuel consumption:

Fuel consumption in Cameroon is the amount of fuel output of the oil deposits for setting national consumption (Ministry of Transports, 2008; Ministry of Energy and Water resources, 2008), because Cameroon does not have the appropriate technology that would permit us to use the Shabbir and Ahmad (2010) method. Therefore, fuel consumption of vehicles can be calculated by the following equation:

$$FC(t) = fuel\ sales(t) \quad (4)$$

3.1.2 Emissions of GHG:

The concept of Global Warming Potential (GWP) is used to allow scientists and policy makers to compare the ability of each GHG to trap heat in the atmosphere with respect to another gas. By definition, the GWP designates the temporal change in radiative forcing due to the instantaneous release of one kilogram of a gas expressed relative to the radiative forcing from the release of one kilogram of CO_2 (IPCC, 2007). The GWP of a GHG counts for both the instantaneous radiative forcing due to increased concentration and lifetime of the GHG concerned. In our study, the GWP for CO_2 is one, that of CH_4 is 21 and that of N_2O is 310 times that of CO_2 (IPCC WG1, 2007).

GHG emissions of vehicles were the product of each type of the fuel consumption (gasoline and diesel) of the vehicles and their emission factors. Following a detailed IPCC bottom-up Tier 2 method, equation (1) can be calculated as follows:

$$GHG\ emissions = (FCi(t) \times Di \times LHVi)(0.99EFi_{CO2} + 21EFi_{CH4} + 310EFi_{N2O}) \quad (5)$$

where, FC*i(t)* is the quantity of fuel consumed in m^3 of fuel vehicle type *i* in year *(t)*, D*i* is the density at 15°C in Mg/m^3 of fuel vehicle type *i*, LHV*i* is the lower heating value in MJ/kg of fuel vehicle type *i*, 0.99 is the fraction of oxidized carbon, EFi_{CO2}, EFi_{CH4} and EFi_{N2O} are emission factors by gas of fuel vehicle type *i* in kg/TJ or kt CO_2-eq/TJ. In addition, D*i*, LHV*i* and EFi_{CO2} are specific to Cameroon (Tamba et al. 2011).

3.1.3 Kaya's approach:

Kaya's equation written in the form (Kaya and Yocobori, 1997):

$$CO_2 = \frac{CO_2}{TOE} \times \frac{TOE}{GDP} \times \frac{GDP}{POP} \times POP \quad (6)$$

tells us that CO_2 emissions depend on the CO_2 content in the energies consumed, the importance energies in the manufacture of the country's wealth, the country's wealth per capita and population.

Fuel consumption from road transport is the main cause for GHG emissions in this sector. The increase in the number of vehicles has resulted in a continuous growth in Cameroon's fuel consumption and has contributed to increase Cameroon's GHG emissions. Hence, travelling contributes by increasing Cameroon's GHG emissions. The movement of the population is possible if and only if incomes are available; hence, GDP also contributes to Cameroon's GHG emissions increase. We find that fuel consumption, GDP, population, and the vehicle fleet are major contributors to Cameroon's GHG emissions increase. Thus, after calculating GHG emissions from the bottom up Tier 2 method by equation (5), and taking into consideration the indicators of this study, equation (6) is transformed by applying a modified Kaya's equation. Therefore, GHG emissions can be calculated as follows:

$$GHG\ emissions(t) = \frac{GHG\ emissions(t)}{FC(t)} \times \frac{FC(t)}{GDP(t)} \times \frac{GDP(t)}{POP(t)} \times \frac{POP(t)}{V(t)} \times V(t) \quad (7)$$

This relationship allows us to express how the total GHG emissions in Cameroon's road transport sector is related to gasoline and diesel consumption on five factors: GHG intensity of fuel consumption, fuel consumption intensity of income production, output GDP per capita, intensity population of vehicle and vehicle itself. The Kaya's method is applied to the global CO_2 emissions whereas the modified form is applied to Cameroon GHG emissions in the road transport sector.

3.2 Data sources:

3.2.1 Emission factors:

The CO_2 emission factors specific to Cameroon used in this study are obtained in the work of Tamba et al. (2011) and are included in the 95% confidence interval of the IPCC. Given the technology difficulty in determining the emission factors of CH_4 and N_2O in Cameroon, we use the default emission factors values from the IPCC (2006). Default emission factors for gasoline are classified as non-controlled motor gasoline and are worth 33 kg/TJ and 3.2 kg/TJ for CH_4 and N_2O respectively. CH_4 and N_2O default emission factors both have a value 3.9 kg/TJ for diesel.

3.2.2 Indicators data:

In Cameroon, the data of the vehicle fleet are often classified by vehicle type (Transtat, 2006; SIE-Cameroon, 2009, 2010) (see Table 1). Henceforth, MV represents the motor vehicles (cars, passenger vehicles and taxis), LO the lorries, BU the bus, AT the articulated lorries and trailers, TR the tractors and MC the motorcycles. However, it is impossible to know the amount of fuel consumed by vehicle type because Cameroon has an old vehicle fleet. Furthermore, the information statistics are unreliable for this classification. Therefore, the present study includes two types of fuel (gasoline and diesel) to classify vehicle fleet by fuel vehicle type. Thus, we use fuel vehicle types (gasoline vehicle and diesel vehicle) to estimate GHG emissions in Cameroon's road transport sector. In addition, the detail of data sources of GDP, population and fuel consumption are obtained from the world bank data (World Bank, 2011), Central Bureau of the Census and population Studies (Bucrep, 2010) and HPSF (2009) respectively (see Table 2).

Table 1: Classification of vehicles

Period	Gasoline Vehicle (*)	Diesel Vehicle (*)	Vehicle Fleet (*)	MV	LO	BU	AT	TR	MC
1995	106333	68055	174388	94757	26868	7158	2554	3048	40003
1996	113495	70926	184421	100939	27380	7366	2723	3175	42838
1997	116066	72300	188366	102249	27758	7586	2896	3385	44492
1998	118907	75020	193927	105866	28564	8088	3070	3538	44801
1999	123492	78456	201948	110777	29105	9313	3087	3718	45948
2000	128129	82147	210276	115918	29631	10725	3106	3909	46987
2001	141574	91454	233028	134507	32075	11734	3191	4102	47419
2002	159209	102469	261678	151853	35255	13758	3220	4680	52912
2003	174515	109312	283827	173137	35490	13908	3250	4723	53319
2004	177617	114177	291794	164429	40577	14937	4133	5201	62517
2005	190080	122179	312259	175981	43417	15982	4422	5564	66893
2006	197683	125974	323657	183020	44064	16622	4598	5784	69569
2007	205591	131012	336603	190341	45827	17287	4782	6015	72351
2008	213815	137435	351250	198954	47783	17978	4993	6296	75246
(*). EETL's estimations and calculations.									

Table 2: Classification of other indicators

Period	GDP in billion US dollars ($)	Population	Gasoline consumption in ktoe	Diesel consumption in ktoe	Total fuel consumption in ktoe
1995	7.99	13357759	242	106	348
1996	8.39	13743798	266	117	383
1997	8.82	14140994	244	129	373
1998	9.26	14536941	271	155	426
1999	9.67	14943976	281	146	427
2000	10.08	15362407	255	173	428
2001	10.53	15792554	262	188	450
2002	10.95	16234746	265	208	473
2003	11.39	16640615	279	205	484
2004	11.82	17056630	289	210	499
2005	12.09	17124857	289	196	485
2006	12.48	17552978	285	197	482
2007	12.91	17991802	295	205	500
2008	13.29	18449486	301	221	522

4.0 Results and Discussions:

Given that the Cameroon vehicle fleet is old of about 30 years, it is impossible to clearly mark out its technological evolution. Thus, during the period 1995-2008, we have considered the emission factors constant to calculate GHG emissions in Cameroon's road transport sector.

4.1 Total GHG emissions in Cameroon's road transport sector:

The results of GHG emissions in Cameroon's road transport sector between 1995 and 2008 are listed in Table 3 while Figure 2 represents the evolution of these GHG emissions. These results come from indicators data associated with the coupling of equations (5) and (7). PVG is the average fraction in percentage of GHG emissions related to gasoline vehicles in road transport. PVD is the average fraction percentage of GHG emissions related to diesel vehicles in road transport. CS-95 represents average annual change since 1995 in percentage of GHG emissions and AC the change over previous year in percentage of GHG emissions.

Table 3: Trends in GHG emissions in Cameroon's road transport

period	Gasoline vehicles				Diesel vehicles				Road transport		
	GHGs (kt CO_2-eq)	PVG (%)	CS-95 (%)	AC (%)	GHGs (kt CO_2-eq)	PVD (%)	CS-95 (%)	AC (%)	GHGs (kt CO_2-eq)	CS-95 (%)	AC (%)
1995	757	68.76	-	-	344	31.24	-	-	1101	-	-
1996	831	68.62	9.78	9.78	380	31.38	10.47	10.47	1211	9.99	9.99
1997	762	64.63	0.66	-8.30	417	35.37	21.22	9.74	1179	7.08	-2.64
1998	846	62.81	11.76	11.02	501	37.19	45.64	20.14	1347	22.34	14.25
1999	876	64.89	15.72	3.55	474	35.11	37.79	-5.39	1350	22.62	0.22
2000	797	58.69	5.28	-9.02	561	41.31	63.08	18.35	1358	23.34	0.59
2001	815	57.15	7.66	2.26	611	42.85	77.62	8.91	1426	29.52	5.01
2002	827	55.02	9.25	1.47	676	44.98	96.51	10.64	1503	36.51	5.40
2003	870	56.68	14.93	5.20	665	43.32	93.31	-1.63	1535	39.42	2.13
2004	899	56.86	18.76	3.33	682	43.14	98.26	2.56	1581	43.60	3.00
2005	904	58.78	19.42	0.56	634	41.22	84.30	-7.04	1538	39.69	-2.72
2006	890	58.25	17.57	-1.55	638	41.75	85.47	0.63	1528	38.78	-0.65
2007	919	57.98	21.40	3.26	666	42.02	93.60	4.39	1585	43.96	3.73
2008	942	56.85	24.44	2.50	715	43.15	107.85	7.36	1657	50.50	4.54

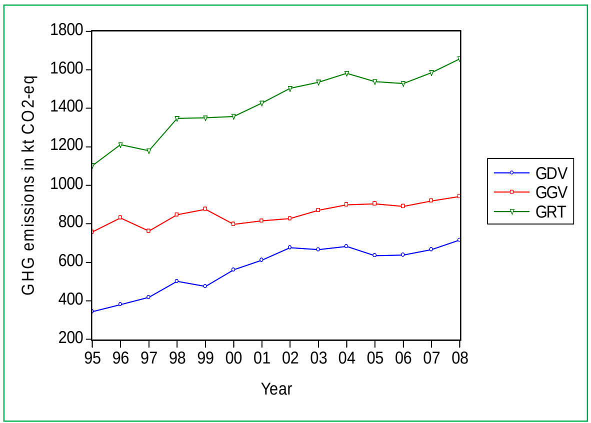

Fig. 2: GHG emissions in Cameroon's road transport

Total GHG emissions in the Cameroon's road transport sector (GRT) are estimated to have increased from 1101 kt CO_2-eq in 1995 to 1657 kt CO_2-eq in 2008. Meanwhile, GHG emissions of gasoline (GGV) and diesel vehicles (GDV) are estimated to have increased from 757 and 344 kt CO_2-eq in 1995 to 942 and 715 kt CO_2-eq in 2008 respectively. Gasoline vehicles contributed about 68.76% and 56.85% of the total GHG emissions in Cameroon's road transport sector (GRT) in 1995 and 2008 respectively, and diesel vehicles the rest. Hence, the growth rate of gasoline vehicles decreases while that of diesel vehicles increases.

Overall, GHG emissions have increased by 50.50% during the period 1995-2008 in the Cameroon's road transport sector. Also, GHG emissions have increased by 24.44% and 107.85% for gasoline vehicles and diesel vehicles respectively from 1995 to 2008. GHG emissions from diesel vehicles have doubled during the period 1995-2008. Although, the growth rate of GHG emissions from diesel vehicles is greater than that of gasoline vehicles, GHG emissions from gasoline vehicles are larger than those of diesel vehicles from 1995 to 2008.

Table 4 shows, in detail, the statistics summary of GHG emissions in Cameroon's road transport. The assessment of the results shows that Cameroon's road transport emits an average of 1421.4 kt CO_2-eq per year. Therefore, gasoline vehicles emit an average of 852.5 kt CO_2-eq per year and 568.9 kt CO_2-eq per year for diesel vehicles, in terms of average annual fraction 59.98% of GHG emissions for gasoline vehicles and 40.02% for diesel vehicles.

In fourteen (14) years, Cameroon's road transport sector has emitted in total 19899 kt CO_2-eq of GHGs into the atmosphere.

Table 4: Summary statistics of GHG emissions

Categories	Gasoline vehicles	Diesel vehicles	Road transport
Mean (kt CO_2-eq)	852.5	568.9	1421.4
Median (kt CO_2-eq)	858.0	622.5	1464.5
Maximum (kt CO_2-eq)	942.0	715.0	1657.0
Minimum (kt CO_2-eq)	757.0	344.0	1101.0
Standard deviation	57.2	123.4	169.3
Sum (kt CO_2-eq)	11935.0	7964.0	19899.0
Observations	14	14	14

As shown in Table 5, CO_2 emissions in Cameroon's road transport sector contribute to GHG emissions with an amount of 1389.17 kt that is an average of 97.73% of emissions. CH_4 and N_2O emissions account for 0.62% (8.75 kt CO_2-eq) and 1.65% (23.48 kt CO_2-eq) of GHG emissions respectively. We find that CO_2 emission in the Cameroon's road transport sector can be assimilated to GHG emissions in terms of annual average (see Figure 3).

Table 5: Annual averages of direct GHG emissions by gas type

Categories	**CO_2 (kt)**	**CH_4 (kt CO_2-eq)**	**N_2O (kt CO_2-eq)**	**GHGs (kt CO_2-eq)**
Road transport	1389.17	8.75	23.48	1421.40
Gasoline vehicles	829.99	8.25	14.26	852.50
Diesel vehicles	559.18	0.50	9.22	568.90

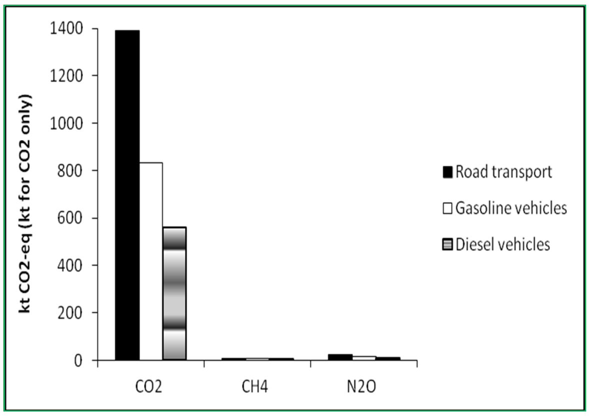

Fig. 3: GHG emissions by sector and by gas type

Assimilating CO_2 emissions to GHG emissions in the Cameroon's road transport sector, Table 6 on its part shows the contribution of CO_2 emissions in the road transport as a fraction of the total CO_2 emissions in Cameroon due to the energy sector. CO_2 emissions are determined by multiplying the GHG emissions in the road transport sector by the annual average fraction of CO_2 in GHG emissions of the period 1995-2008. The total CO_2 emissions in Cameroon due to the energy sector are obtained from World Bank data (World Bank, 2012). The CO_2 emissions in road transport are higher than the quarter of total CO_2 emissions. In 2002, we noticed the highest emissions of CO_2 in road transport, with about 42.98%. Road transport sector related emissions account for 30.55% of Cameroon's total GHG emissions in 2008. Overall, the CO_2 emissions in the road transport sector have 34.33% of contribution of the total CO_2 emissions in Cameroon due to the energy sector in terms of annual average from 1995 to 2008.

4.2: Impacts of GHG emissions in Cameroon's road transport in terms of indicators

Table 7 shows the GHG emissions in relation to some indicators for gasoline vehicles category. CS-95 represents average annual change since 1995 and AC the change over previous year. We clearly see that the amount of GHGs emitted by gasoline vehicles per gasoline consumption (kt CO_2-eq/ktoe) is almost constant from 1995 to 2008 while the amount of GHG emitted per gasoline vehicles (kt CO_2-eq/vehicle) decreased by 38.12% over the same period. These trends are summarized graphically in Figure. 4.

GAC represents the amount of gasoline consumption (ktoe), GAV the number of gasoline vehicles, GGV the GHG emissions for gasoline vehicles (kt CO_2-eq), GPG the amount of GHG emissions per gasoline consumed (kt CO_2-eq/ ktoe), and GPGV the amount of GHG emissions per gasoline vehicles (kt CO_2-eq/ vehicle). The indexed curves clearly show that GHG emissions from gasoline vehicles are proportional to the gasoline consumption and the amount of GHG emissions per gasoline consumption is constant (see Figure 4). However, the number of gasoline vehicles is growing faster than GHG emissions due to gasoline vehicles, which implies the reduction of GHG emissions in gasoline vehicles category from 1995 to 2008.

Table 6: Fraction of CO_2 emissions in road transport in total CO_2 emissions

Period	Total CO_2 emissions world data bank (kt)	CO_2 emissions in road transport (kt)	Fraction (%)
1995	4364	1075	24.63
1996	4602	1183	25.71
1997	3216	1152	35.82
1998	3209	1317	41.04
1999	3080	1319	42.82
2000	3432	1327	38.67
2001	3421	1395	40.78
2002	3418	1469	42.98
2003	3795	1500	39.53
2004	3957	1546	39.07
2005	3692	1503	40.71
2006	4265	1494	35.03
2007	6168	1549	25.11
2008	5302	1620	30.55

Table 7: GHG emissions per indicator from gasoline vehicles

Period	GHG emissions from gasoline vehicles per gasoline consumption			GHG emissions from gasoline vehicles per vehicle		
	kt CO_2-eq/ktoe	CS-95 (%)	AC (%)	kt CO_2-eq/vehicle	CS-95 (%)	AC (%)
1995	3.128	-	-	0.00712	-	-
1996	3.124	-0.13	-0.13	0.00732	2.85	2.85
1997	3.123	-0.16	-0.04	0.00657	-7.78	-10.33
1998	3.122	-0.20	-0.04	0.00711	-0.06	8.37
1999	3.117	-0.34	-0.14	0.00709	-0.36	-0.30
2000	3.125	-0.08	0.26	0.00622	-12.63	-12.31
2001	3.111	-0.56	-0.47	0.00576	-19.14	-7.45
2002	3.121	-0.23	0.32	0.00519	-27.04	-9.77
2003	3.118	-0.31	-0.08	0.00499	-29.97	-4.03
2004	3.111	-0.56	-0.24	0.00506	-28.90	1.53
2005	3.128	0.00	0.56	0.00476	-33.20	-6.04
2006	3.123	-0.17	-0.17	0.00450	-36.76	-5.34
2007	3.115	-0.41	-0.24	0.00447	-37.21	-0.71
2008	3.130	0.05	0.46	0.00441	-38.12	-1.44

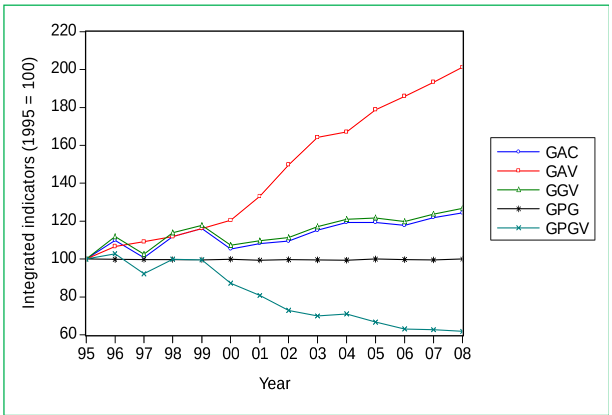

Fig. 4: Indicator trends of GHG emissions from gasoline vehicles

In contrast to GHG emissions of gasoline vehicles per vehicle, the diesel vehicle emissions increased with a growth rate of 2.92% between 1995 and 2008 and GHG emissions up to 0.00683 kt CO_2-eq/ vehicle in 2000. Hence a rate of 35.11% growth compared to that of 1995. However, the amount of GHG emitted per diesel consumption (kt CO_2-eq/ktoe) has a little bit decreased from 1995 to 2008 (see Table 8). These trends are summarized graphically in Figure 5. DIC represents the amount of diesel consumption (ktoe), DIV the number of diesel vehicle, GDV the GHG emissions for diesel vehicle (kt CO_2-eq), GPD the amount of GHG emissions per diesel consumption (kt CO_2-eq/ ktoe), and GPDV the amount of GHG emissions per diesel vehicle (kt CO_2-eq/ vehicle). The indexed curves clearly show that GHG emissions due to diesel vehicles increase faster than the number of diesel vehicles from 1995 to 2008 and the amount of GHG emissions per diesel consumption is constant (see Figure 5). GHG emissions from diesel vehicles are proportional to the diesel consumption. From GHG emissions per vehicle point of view, the results show that the category of diesel vehicle emits more GHGs than gasoline vehicle.

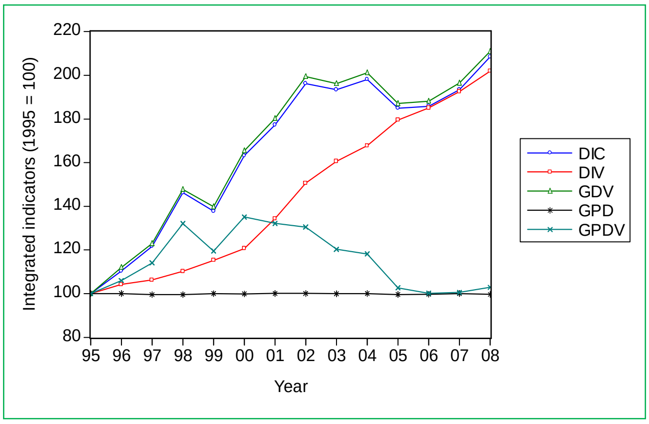

Fig. 5: Indicator trends of GHG emissions from diesel vehicle

For GHG emissions in Cameroon's road transport sector, Table 9 shows the GHG emissions in relation to indicators between 1995 and 2008. It shows clearly that the increase of 8.96% of GHG emissions per capita over the past fourteen (14) years has greatly exceeded the changes of GHG emissions per total fuel consumption (0.33%), per GDP (-9.52%) and per vehicle (-25.28%).

These trends are graphically summarized in Figure 6; where GRT represents GHG emissions in road transport (kt CO_2-eq), FUC the amount of total fuel consumption (ktoe), FUV the number of vehicle fleet, GPF the amount of GHG emissions per total fuel consumption (kt CO_2-eq/ ktoe), GPFV the amount of GHG emissions per vehicle fleet, GDP the Gross Domestic Product in billion US$, CAP the number of inhabitant or capita, GGDP the amount of GHG emissions per GDP (kt CO_2-eq/ billion US$) and GCAP the amount of GHG emissions per capita (kt CO_2-eq/ capita). The indexed curves clearly show that GHG emissions in Cameroon's road transport are proportional on the total fuel consumption (see Figure 6). GHG emissions per total fuel consumption (GPF) have remained stable over the study period while the economic intensity of GHG emissions (GGDP) decreased. Another important trend is that the increasing vehicle fleet and GDP were greater than GHG emissions between 1995 and 2008. In general, the decrease in GHG emissions per GDP and per vehicle does not prevent GHG emissions in road transport to grow over the period.

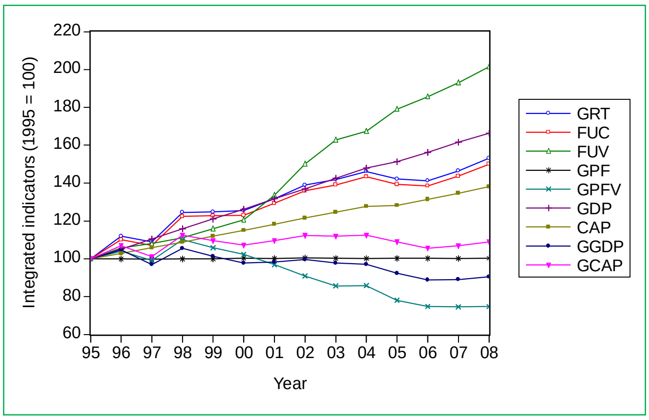

Fig. 6: Indicator trends of GHG emissions from road transport

Table 8: GHG emissions per indicator from diesel vehicles

Period	GHG emissions from diesel vehicles per diesel consumption			GHG emissions from diesel vehicles per vehicle		
	kt CO_2-eq/ktoe	CS-95 (%)	AC (%)	kt CO_2-eq/vehicle	CS-95 (%)	AC (%)
1995	3.245	-	-	0.00505	-	-
1996	3.248	0.08	0.08	0.00536	5.99	5.99
1997	3.233	-0.39	-0.47	0.00577	14.10	7.65
1998	3.232	-0.40	-0.01	0.00668	32.12	15.79
1999	3.247	0.04	0.44	0.00604	19.52	-9.53
2000	3.243	-0.08	-0.12	0.00683	35.11	13.04
2001	3.250	0.15	0.22	0.00668	32.17	-2.17
2002	3.250	0.15	0.00	0.00660	30.51	-1.25
2003	3.244	-0.04	-0.19	0.00608	20.35	-7.79
2004	3.248	0.07	0.11	0.00597	18.17	-1.81
2005	3.235	-0.33	-0.40	0.00519	2.66	-13.13
2006	3.239	-0.21	0.12	0.00506	0.19	-2.40
2007	3.249	0.11	0.32	0.00508	0.57	0.37
2008	3.235	-0.31	-0.42	0.00520	2.92	2.34

Table 9: GHG emissions per indicator from the road transport sector

Period	GHG emissions in the road transport per total fuel consumption			GHG emissions in the road transport per vehicle		
	kt CO_2-eq/ktoe	CS-95 (%)	AC (%)	kt CO_2-eq/vehicle	CS-95 (%)	AC (%)
1995	3.164	-	-	0.00631	-	-
1996	3.162	-0.06	-0.06	0.00657	4.01	4.01
1997	3.161	-0.09	-0.03	0.00626	-0.86	-4.68
1998	3.162	-0.06	0.04	0.00695	10.02	10.97
1999	3.162	-0.07	-0.01	0.00668	5.88	-3.76
2000	3.173	0.29	0.36	0.00646	2.29	-3.39
2001	3.169	0.16	-0.13	0.00612	-3.07	-5.25
2002	3.178	0.44	0.27	0.00574	-9.03	-6.14
2003	3.171	0.24	-0.19	0.00541	-14.34	-5.84
2004	3.168	0.14	-0.10	0.00542	-14.18	0.18
2005	3.171	0.23	0.09	0.00493	-21.99	-9.10
2006	3.170	0.20	-0.03	0.00472	-25.22	-4.15
2007	3.170	0.20	0.00	0.00471	-25.42	-0.26
2008	3.174	0.33	0.14	0.00472	-25.28	0.18
Period	GHG emissions in the road transport per GDP			GHG emissions in the road transport per capita		
	kt CO_2-eq/ billion US$	CS-95 (%)	AC (%)	kt CO_2-eq/10^3 capita	CS-95 (%)	AC (%)
1995	137.797	-	-	0.0824	-	-
1996	144.338	4.75	4.75	0.0881	6.90	6.90
1997	133.673	-2.99	-7.39	0.0834	1.15	-5.38
1998	145.464	5.56	8.82	0.0927	12.42	11.14
1999	139.607	1.31	-4.03	0.0903	9.60	-2.51
2000	134.722	-2.23	-3.50	0.0884	7.25	-2.15
2001	135.423	-1.72	0.52	0.0903	9.55	2.15
2002	137.260	-0.39	1.36	0.0926	12.32	2.53
2003	134.767	-2.20	-1.82	0.0922	11.91	-0.36
2004	133.756	-2.93	-0.75	0.0927	12.46	0.48
2005	127.213	-7.68	-4.89	0.0898	8.96	-3.11
2006	122.436	-11.15	-3.75	0.0871	5.61	-3.07
2007	122.773	-10.90	0.28	0.0881	6.88	1.20
2008	124.680	-9.52	1.55	0.0898	8.96	1.95

5.0 Conclusion:

This study was carried out to estimate the trends of GHG emissions in the Cameroon's road transport sector with methods other than Tier 1 of the IPCC between 1995 and 2008. The results of this study show that the total estimated direct GHG emission amounts to 1421.4 kt CO_2-eq in road transport sector, with 97.73% from CO_2 emissions and 2.27% from non-CO_2 emissions in terms of annual average in the period of study. On the sectoral basis, gasoline vehicles emit 59.98% of total GHG emissions in road transport in terms of the annual average fraction and 40.02% for diesel vehicles. Even though the growth rate of GHG emissions from diesel vehicles (107.85%) from 1995 to 2008 is much considerable than that of gasoline vehicles (24.44%), GHG emissions from gasoline vehicles are greater than those of diesel vehicles. For impacts of GHG emissions in terms of indicators in the Cameroon's road transport sector, GHG emissions grow in the same direction as the number of vehicle fleet, total fuel consumption, number of inhabitants and GDP. Compared to the data of total CO_2 emissions of Cameroon from the world bank data, road transport emits more than a quarter of CO_2 emissions.

The results of this study equally show that GHG emissions increase with time. Given the amount of GHGs emitted into the atmosphere by the road transport sector, mitigation policies must be taken, preferably by considering the realities of Cameroon. As a Non-Annex 1 party, Cameroon's government has the right to insure favorable conditions to its development, which inevitably requires the heavily investment in the promotion of alternative vehicle and fuel by developing socioeconomic and scientific research in the Cameroon's road transport sector.

From a technological point of view, in the short-run, the Cameroonian government must rejuvenate its vehicle fleet. The current vehicles must be replaced and increased by clean vehicles. Thus, gasoline and diesel vehicles can be renewed by liquefied petroleum gas and compressed natural gas vehicles because Cameroon has a natural gas field of about 186 billion cubic meters (SIE-Cameroon, 2009, 2010). In the long-run, the efforts to promote the development and diffusion of electric and hybrid electric vehicles are important to mitigate GHG emissions in the Cameroon's road transport sector.

Cameroon's environmental strategy aims at reducing the consumption of petroleum products by alternative fuel in the road transport sector. Thus, diffusion and propagation of pure vegetable oil, bio-gas, bio-ethanol and bio-diesel vehicles will contribute to the mitigation of GHG emissions in the road transport sector. From an economic point of view, the government of Cameroon should put in place a strategy in order to know the exact number and type of used and non-controlled vehicles. Then, the tax on used and non-controlled vehicles must be increased. This tax will reduce the flow of used and non-controlled vehicles and increase that of new and low-carbon technology vehicles. Currently, apart from public transport vehicles, private or passenger vehicles are not all subject to technical inspection even if regulations permit it. Thus, a tax must be established to develop technical control for all types of vehicles. This measure will contribute to mitigate the GHG emissions in the Cameroon's road transport sector. In addition, the government could increase the fuel tax at the pump for vehicle of important capacities.

Furthermore, mitigation policies must also be directed on socioeconomics actions such as: improving roads to facilitate transport of the population and thus reducing GHG emissions; the introduction of properly adjusted traffic signals for the efficient flow of vehicles; strengthening vehicle fuel economy with implementation of passenger vehicles fuel economy standard; reducing public transport fare in order to reduce the number of passenger vehicles; improving traffic management systems and facilitating urban public transport development with the construction/building of public transport infrastructure; the entry into circulation of coaches (big buses) for public transport instead of mini buses; extension of non-motorized transport and the introduction of the concept of GHG emissions in driving schools. Overall, Cameroon is willing to contribute to the world's effort to fight against climate change.

Finally, this study would help in improving the Cameroon second National Communication of GHG emissions inventories to the UNFCCC. This is one of the first GHG inventory for road transport category in Cameroon. However, the guidelines of the UNFCCC on GHG inventories state that "Parties shall communicate to the Conference of Parties a National inventory of anthropogenic emissions according to their capacities".

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