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CARBON INTENSITY OF THE ENERGY SECTOR FOR TOGO IN 2012

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ABSTRACT

Togo, a least developed country, is ambitious to emerge by 2030 and the energy parameter remains indispensable with concerns as a source of emission of greenhouse gases. This study analyzed carbon intensity in the energy sector in Togo in 2012 in order to provide decision-makers, producers, distributors and final consumers with reliable data to achieve the objective of low carbon development in compliance with Togo's commitment in its Nationally Determined Planned Contributions (CPDN). In line with the IPCC 2006 methodologies, greenhouse gas emissions in 2012 in Togo are estimated at 1856.202 Gg for carbon dioxide (CO_2), 15.352 Gg for methane (CH_4) and 0.2431 Gg For nitrous oxide (N_2O), i.e. a total of 2253,955 Gg CO_2equivalent(Gg CO_2-eq) of direct GHGs. Indirect GHGs are emitted at 558.525Gg, 7.942Gg, 34.252Gg and 2.563Gg respectively for carbon monoxide (CO), nitrogen oxides (NOx), volatile organic compounds (NMVOCs) and sulfur dioxide (SO_2). The carbon intensity linked to the Energy sector in Togo amounts to $1,797x10^{-9}$ Gg CO_2-eq / GDP, at a time when the standard of living was $ US 319.222 per Capita. Road transport, with 1368 Gg of CO_2 emissions accounting for 55.4% of total direct GHG emissions, is the first key source. With an uncertainty of about ± 23.887% on the overall estimate and a relative difference of 12.37% between the CO_2 estimates by the sectoral and reference methods, the inventory is coherent as a whole.

KEYWORDS: Green House Gas (GHG), Carbon Intensity, Energy, GDP.

INTRODUCTION

Togo is currently characterized by three main sources of energy consumption, namely Manufacturing and Construction Industries, Transport and Residential, Commerce and Institutions. Manufacturing and construction industries include food, beverages and tobacco; the textile; Clothing; Wood and wooden articles; Printing works; the paper; Publishing; The chemical and metal industries, and the mining and quarrying industries (phosphates, clinker). The current transport system consists of road, rail, domestic and maritime modes. In the residential, commercial and institutional sectors, energy consumption is dominated by activities in households and large institutions such as large stores, major administrations, universities, schools, hotels, embassies and banks.

The rapid appraisal and analysis of the 2012 Gaps entitled "Sustainable Energy for All" (*UNDP, 2012*) indicated that the final energy consumption in 2008 was 1,949.61 Ktoe, of which 1,468.71 Ktoe in biomass (firewood, charcoal and agricultural residues) or 75.3%; 426.12 Ktoe in petroleum products (21.8%) and only 54.78 Ktoe in electricity (2.8%). Although Togo is an importer of electricity from neighboring countries, national needs are complemented using fuel-fired power plants (diesel, jet fuel) and biomass.

As a least developed country, Togo wants to emerge by 2030 and the energy parameter remains very indispensable and therefore a source of greenhouse gas emissions. This study analyzed carbon intensity in the energy sector in Togo in 2012 in order to provide decision-makers, producers, distributors and final consumers with reliable data to achieve the objective of low carbon development in compliance of Togo's commitment contained in its intended Nationally Determined Contribution (INDC). The analysis in this study focuses on the carbon intensity of the three (03) direct greenhouse gases, namely carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O).

2. MATERIAL AND METHODS

2.1. MATERIAL

The data collection sheets and the solicitation letters were used to gather the necessary quantitative data. The Intergovernmental Panel on Climate Change (IPCC) Emission Factor Data Base (EFDB) was used as a tool for collecting emission and conversion factors. The IPCC manuals for Greenhouse Gas Inventory (GHG) inventories were used as a planning guide. Data analysis is done with the reference tool for the calculation of GHG emissions from energy consumption, namely the IPCC methodologies and the IPCC Inventory Software (*IPCC, 2006*). Decision trees were used to

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choose methodological tier levels in accordance with the IPCC Good Practice Guidelines.

2.2. METHODS

Statistical data on imports, changes in fuel stocks and detailed statistics on final consumption were collected at the Ministry of Trade and Industry and specifically at the Directorate General of Energy and the data for the balance sheets Energy projects are collected at the Directorate-General for Energy. The same data were collected from oil companies, manufacturing industries, businesses and institutions. Surveys in the household and transport sub-sectors have enriched the database of annual fuel consumption such as kerosene, diesel, gasoline, LPG, heavy fuel oil, coal and fuel wood. Two Tier 1 methods were considered in accordance with the IPCC 2006 guidelines. These are:

- the Level 1 reference approach that provides only aggregate emissions estimates by fuel type, distinguishing between primary and secondary fuels, and
- the Tier 1 sectoral approach based on end-use data, combustion types and industry-specific technology where known.

The basic equation used for emission calculation is given by: $\boldsymbol{Emission_{GES,comb}} = \boldsymbol{consom._{comb}}$ x $\boldsymbol{EF_{GES,comb}}$

Where:

- $Émission_{GEScomb}$ = Emissions of a given GHG by fuel type (kg GHG)
- Combustible fuel consumption = Amount of burned fuel (TJ)
- GES emission factor, comb. = Default emission factor of a given GHG by fuel type (kg gas / TJ).

RESULTS AND DISCUSSION

Data collection provided the input parameters for the Tier 1 methods approach which uses the Activity Data (AD) and the Emission Factors (EF) as well as the associated uncertainties (Table 1). The uncertainties on the EF and parameters are and parameters are the IPCC default data. Fuel consumption was collected for subcategories 1A1 to 1A4 according to the IPCC 2006 nomenclature.

Table 1: Fuel consumption data for 2012 in Togo

Fuel	EF	AD	DATA UNCERTAINTY
1.A.1.a.i - Electricity Generation			
Jet Kerosene	44.1 TJ/Unit	1.6 Gg	15%
Gas/Diesel Oil	43 TJ/Unit	2 Gg	15%
1.A.2.e - Food Processing, Beverages and Tobacco			
Gas/Diesel Oil	43 TJ/Unit	1.6 Gg	10%
1.A.2.f - Non-Metallic Minerals			
Residual Fuel Oil	40.4 TJ/Unit	45 Gg	10%
1.A.3.a.i - International Aviation (International Bunkers)			
Jet Kerosene	44.1 TJ/Unit	78 Gg	20%
1.A.3.b - Road Transportation			
MotorGasoline	44.3 TJ/Unit	145.4 Gg	20%
Gas/Diesel Oil	43 TJ/Unit	252 Gg	20%
1.A.4.a - Commercial/Institutional			
Wood/Wood Waste	1 TJ/Unit	6207 Tj	25%
Charcoal	29.5 TJ/Unit	32 Gg	25%
1.A.4.b - Residential			
OtherKerosene	43.8 TJ/Unit	56.5 Gg	20% - 25%
Liquefied Petroleum Gases	47.3 TJ/Unit	6.5 Gg	20% - 25%
Wood/Wood Waste	1 TJ/Unit	31487 Tj	20% - 25%
Charcoal	29.5 TJ/Unit	603 Gg	20% - 25%

The aggregate emissions data for 2012 are reflected in the table in decision 17 of the eighth Conference of the Parties to the UNFCCC (*Table 17/CP.8*).

Table 2: Aggregate emissions data (*Table 17/CP.8*) Inventory Year: 2012

Greenhousegas source and sinkcategories	CO_2 (Gg)	CH_4 (Gg)	N_2O (Gg)	CO Gg	NOx (Gg)	NMVOCs (Gg)	SOx (Gg)
1 – Energy	1856.202	15.352	0.2431	558.525	7.942	34.252	2.563
1A - Fuel Combustion Activities	1856.202	15.352	0.2431	558.525	7.942	34.252	2.563
1A1 - Energy Industries	11.418	0,001	NE	NE	NE	NE	NE
1A2 - Manufacturing Industries and Construction	152.184	0.014	0.0022	NE	NE	NE	NE
1A3 - Transport	1495.270	0.257	0.070	81.492	1.67	9.7623	2.563
1A4 – OtherSectors	197.331	15.081	0.171	477.033	6.272	24.490	NE
1A5 – Other	NO	NO	NO	NO	NO	NO	NO
1B - Fugitive Emissions from Fuels	0	0	0	0	0	0	0
1B1 - Solid Fuels	NE	NE	NE	NE	NE	NE	NE
1B2 - Oil and Natural Gas	NE	NE	NE	NE	NE	NE	NE

Source: Authors, based on the estimation
NB: NE=Not estimeted ; NO = Not Occuring

Energy sources in Togo are in four sub-categories: Energy Industries (1A1), Manufacturing Industries and Construction (1A2), Transport (1A3) and Other Sectors, i.e. Residential and Commercial & Institutions (1A4); based on the results in Table 17/CP.8.

Since sources of fugitive emissions (category 1B) are insignificant because Togo does not have extractive industries, emissions from the sector are therefore allocated only to fuel combustion in category 1A. Fuel combustion activities are mainly related to two main sources: stationary combustion in energy industries that include energy extraction, energy production and transformation; In the manufacturing and construction industries; In the construction industry (shops and institutions); In the residential for lighting, cooking, heating; And in agriculture / forest / fishing and mobile transport-related combustion such as aviation (civil and military); The road (cars, vehicles and motorcycles); The railways (transport of phosphates and clinker) and navigation.

Emissions are estimated at 1856.202 Gg for carbon dioxide (CO_2), 15.352 Gg for methane (CH_4) and 0.2431 Gg for nitrous oxide (N_2O) for a total of 2253.955 Gg CO_2-eq of direct GHGs emitted on the basis of Global Warming Potentials (GWP 100) whose values are 1, 21 and 310 respectively for CO_2, CH_4 and N_2O.Carbon dioxide (CO_2) emissions are in the proportions (*Figure 1*) of 80.56% for Transport (1A3); 10.63% for Residential, Commerce and Institution (1A4); 8.20% for Manufacturing and Construction Industries (1A2) and 0.62% for Energy Industries (1A1).

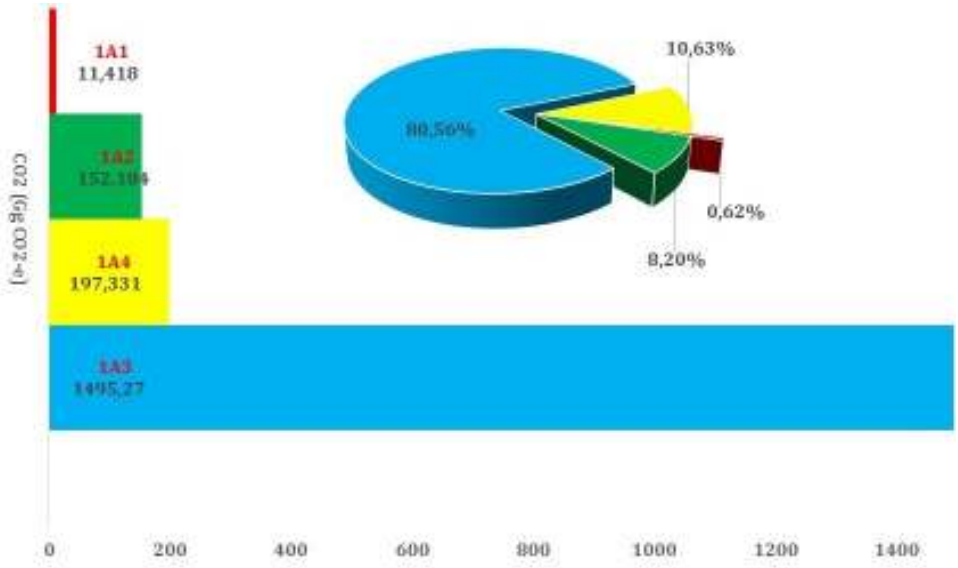

Figure 1: Carbondioxide (CO_2)emissions by subcategory
Source: Authors, based on the emissions of GHG estimated

The distribution of methane (CH_4) emissions amounts to 98.23% (*Figure 2*), almost all to the Residential, Commerce and Institutions (1A4) sub-category. Other contributions are low at 1.67%; 0.09% and 0.01% respectively to the subcategories Transport (1A3); Manufacturing and Construction Industries (1A2) and Energy Industries (1A1).

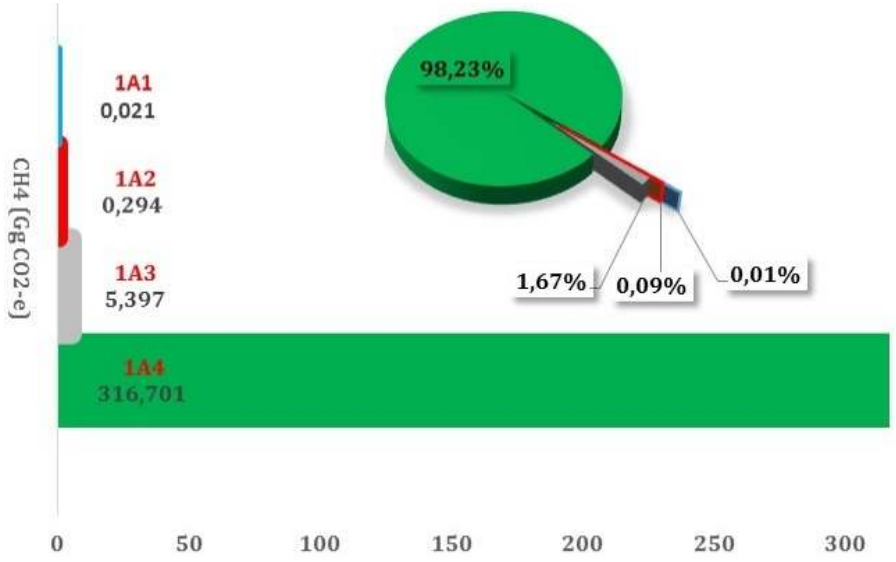

Figure 2: Methane (CH_4)emissions by subcategory
Source ***: Authors, based on the emissions of GHG estimated***

The main source of emission of nitrous oxide (N_2O) is also the Residential, Commerce and Institutions (1A4) sub-category with 70.31% (*Figure 3*). It is followed by Transport (1A3) with 28.78%. Emissions in the Manufacturing and Construction Industries (1A2) of N_2O are estimated at 0.682 Gg CO_2-eq which is close to 0.90%, while they are zero in the Energy Industry.

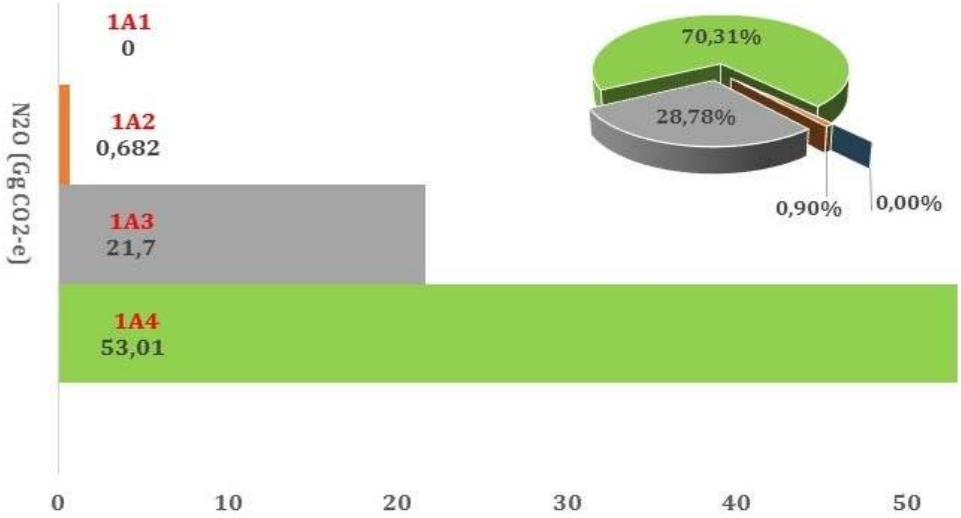

Figure 3: Nitousoxide (N_2O) emissions by sub-category
Source: Authors, based on the emissions of GHG estimated

Carbon monoxide (CO), nitrogen oxides (NOx), volatile organic compounds (NMVOCs) and sulfur dioxide (SO_2) are the indirect GHGs emitted by fuel combustion in the two (02) subsectors Transport (1A3) and Residential, Commerce and Institutions (1A4) as shown in Table 3 and Figure 4.

Table 3: Emission results per gas

Gas	subsector Transport: 1A3	subsector Transport: 1A4
CO	81.492 Gg	477.033 Gg
NOx	1.670 Gg	6.272 Gg
NMVOC	9.762 Gg	24.490 Gg
SO_2	2.563 Gg	0.000 Gg

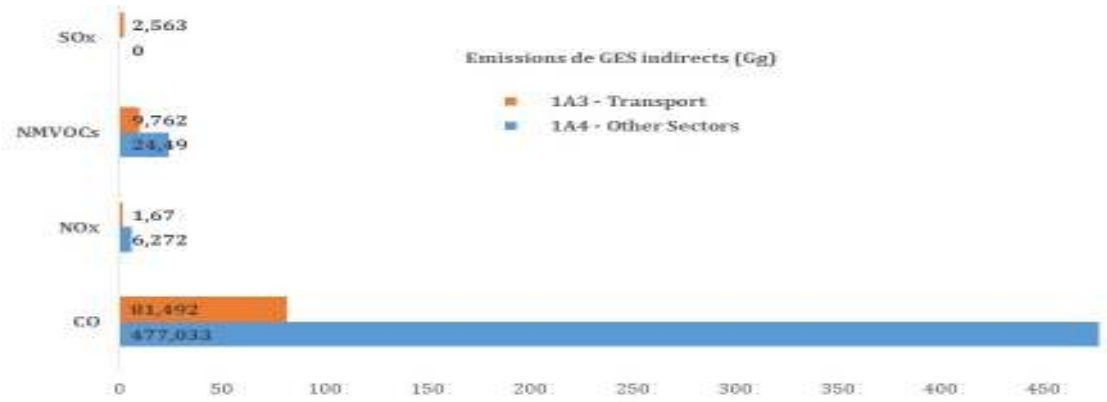

Figure 4: Indirect GHG emissions by sub-category
Source: Authors, based on the emissions of GHG estimated

The carbon intensity was analyzed as a ratio between its CO_2 emissions and its wealth production. Considering all economic sectors as well as all energy sources, this indicator reflects the emission level of the industry, the nature of transport and the level of Togo's use of carbon. The analysis only considers estimated direct greenhouse gas emissions. In 2012, the Togolese population was estimated at 6,547,806 inhabitants and the Gross Domestic Product (GDP) at constant prices based on the year 2000 was 2,090,204,649.530 $ USwith a decay rate of 4.807% (MEF, 2017). Aggregated direct greenhouse gas (GHG) emissions are estimated at 2,253,955 Gg CO_2-eq in the same year. The sector's carbon intensity in 2012 is equivalent to $1{,}797x10^{-9}$ Gg CO_2-eq / GDP, and at that time the standard of living in Togo was $ US319.222per inhabitant. Assuming a Business as Usual (BaU) for which the standard of living would remain constant over the period 2000 to 2015, the annual emission (Gg CO_2-eq) in the Energy sector could be expressed by the equation:

$E_{ES} = 0{,}344x10^{-3}$ x Pop

With: E = Emission ; ES= Energy Sector and Pop = Population

From this relationship are deducted emissions giving the trend over the period 2000 to 2015 in the Energy sector (*Table 4*). *Figure 5*, showing the change in GDP emissions at constant prices, showed a strong correlation between emissions and GDP.

Table 4: GDP and emissionsdeductedfromcarbonintensity

Année	2000	2001	2002	2003
PIB (10^6 $ US)	1535.657	1515.673	1496.080	1567.695
Emission ($GgCO_2$-eq)	1592.376	1630.560	1669.693	1709.766

Année	2004	2005	2006	2007
PIB (10^6 $ US)	1606.353	1626.429	1690.370	1726.233
Emission ($GgCO_2$-eq)	1750.800	1792.820	1835.847	1879.908

Année	2008	2009	2010	2011
PIB (10^6 $ US)	1768.032	1828.531	1902.114	1994.332
Emission ($GgCO_2$-eq)	1925.025	1971.226	2129.757	2190.242

Année	2012	2013	2014	2015
PIB (10^6 $ US)	2090.205	2173.140	2300.741	2424.196
Emission ($GgCO_2$-eq)	2252.445	2316.415	2382.201	2449.855

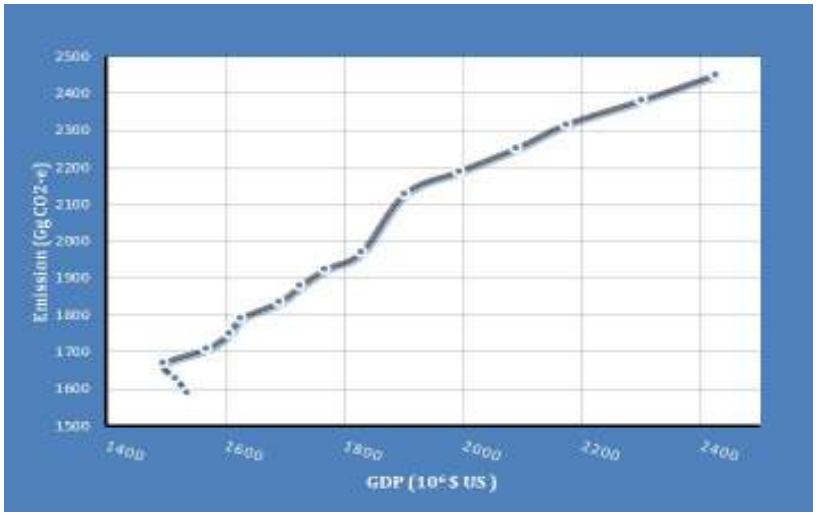

Figure 5: Trend in emissions by GDP
Source : Authors, based on the data and emissions of GHG estimated

The uncertainty of the overall inventory is estimated in 2012 at ± 23,887% and details on sources of uncertainty are compiled in *Table 5*. The highest uncertainties, compared to the average, range from 32,016% to 53,852 % and refer to the estimates of nitrous oxide (N_2O), methane (CH_4) and carbon dioxide (CO_2) attributable to the combustion of biomass and fuel oil in the residential, commercial and industrial sectors and road.

Table 5: Uncertainty of emissions

2006 IPCC Categories	Gas	2012 emissions ($GgCO_2$-eq)	AD Uncertainty (%)	EF ncertainty (%)	Combined Uncertainty (%)
1.A - Fuel Combustion Activities					
1.A.1.a.i - ElectricityGeneration - Liquid Fuels	CO_2	11.418	15	15	21.213
1.A.1.a.i - ElectricityGeneration - Liquid Fuels	CH_4	0.010	15	20	25.000
1.A.1.a.i - ElectricityGeneration - Liquid Fuels	N_2O	0.029	15	25	29.155
1.A.2.e - Food Processing, Beverages and Tobacco - Liquid Fuels	CO_2	5.098	10	15	18.028
1.A.2.e - Food Processing, Beverages and Tobacco - Liquid Fuels	CH_4	0.004	10	20	22.361
1.A.2.e - Food Processing, Beverages and Tobacco - Liquid Fuels	N_2O	0.013	10	25	26.926
1.A.2.f - Non-MetallicMinerals - Liquid Fuels	CO_2	140.713	5	5	7.071
1.A.2.f - Non-MetallicMinerals - Liquid Fuels	CH_4	0.115	5	5	7.071
1.A.2.f - Non-MetallicMinerals - Liquid Fuels	N_2O	0,338	5	5	7.071
1.A.2.m - Non-specifiedIndustry - Liquid Fuels	CO_2	6.373	5	5	7.071
1.A.2.m - Non-specifiedIndustry - Liquid Fuels	CH_4	0.005	5	5	7.071
1.A.2.m - Non-specifiedIndustry - Liquid Fuels	N_2O	0.016	5	5	7.071
1.A.2.m - Non-specifiedIndustry - Biomass	CO_2	29.344	5	5	7.071
1.A.2.m - Non-specifiedIndustry - Biomass	CH_4	0.165	5	5	7.071
1.A.2.m - Non-specifiedIndustry - Biomass	N_2O	0.325	5	5	7.071
1.A.3.a.i - International Aviation (International Bunkers) - Liquid Fuels	CO_2	0.000	5	5	7.071
1.A.3.a.i - International Aviation (International Bunkers) - Liquid Fuels	CH_4	0.000	5	5	7.071
1.A.3.a.i - International Aviation (International Bunkers) - Liquid Fuels	N_2O	0.000	5	5	7.071
1.A.3.a.ii - Domestic Aviation - Liquid Fuels	CO_2	245.946	5	5	7.071
1.A.3.a.ii - Domestic Aviation - Liquid Fuels	CH_4	0,036	5	5	7.071
1.A.3.a.ii - Domestic Aviation - Liquid Fuels	N_2O	2.133	5	5	7.071
1.A.3.b - Road Transportation - Liquid Fuels	CO_2	1249.324	20	25	32.016
1.A.3.b - Road Transportation - Liquid Fuels	CH_4	5.351	20	30	36.056
1.A.3.b - Road Transportation - Liquid Fuels	N_2O	19.490	20	35	40.311
1.A.4.a - Commercial/Institutional - Biomass	CO_2	800.912	20	30	36.056
1.A.4.a - Commercial/Institutional - Biomass	CH_4	43.069	20	35	40.311
1.A.4.a - Commercial/Institutional - Biomass	N_2O	7.989	20	40	44.721
1.A.4.b - Residential - Liquid Fuels	CO_2	197.331	20	25	32.016
1.A.4.b - Residential - Liquid Fuels	CH_4	0.552	20	30	36.056
1.A.4.b - Residential - Liquid Fuels	N_2O	0.470	20	40	44.721
1.A.4.b - Residential - Biomass	CO_2	5518.856	20	30	36.056
1.A.4.b - Residential - Biomass	CH_4	273.080	20	40	44.721
1.A.4.b - Residential - Biomass	N_2O	44.558	20	50	53.852
		Sum(D): 8603,063	Sum(H): 570.599		
			Uncertainty in total inventory: 23.887		

Source: Authors, based on the estimation

The Tier 1 baseline approach provided the aggregate estimates of fuel emissions at 1967.522 Gg. Compared to the Tier 1 sectoral method, the carbon dioxide (CO_2) emission of the fuel is 1856.202 Gg, i.e. a relative difference of approximately 06%, which reflects consistency in the estimates.

In 2012 in Togo, key categories analysis of emission sources by level assessment and trend assessment indicates five (05) subcategories:

(a) 1.A.3.b - Road transport: 1249,324 Gg CO_2-eq of carbon dioxide (CO_2), i.e. a contribution of 55.40% to emissions;

(b) 1.A.4 - Other sectors: 316,149 Gg CO_2-eq methane (CH_4) is a contribution of 14,00%;

(c) 1.A.3.a - Civil aviation: 245.946 Gg CO_2-eq of carbon dioxide (CO_2) or a contribution of 10.90% to emissions;

(d) 1.A.4 - Other Sectors - Liquid Fuels: 197,331Gg CO_2-eq of carbon dioxide (CO_2) or a contribution of 08.80% to emissions; and

(e) 1. A.2 - Manufacturing and construction industries: 152.184 Gg CO_2-eq of carbon dioxide (CO_2) or a contribution of 06.80% to emissions.

During national communications (CNI, DCN, TCN), the road transport sub-category was the first key source. Indeed, it is a sector in full evolution with the increase of traffic in the big cities.

CONCLUSION

According to the 2006 IPCC methodologies, greenhouse gas emissions in 2012 in Togo are divided between carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), nitrogen oxides (NO_X), carbon monoxide (CO) and NMVOCs. Emissions are estimated at 1856.202 Gg for carbon dioxide (CO_2), 15.352 Gg for methane (CH_4) and 0.2431 Gg for nitrous oxide (N_2O), for a total of 2253.955 Gg CO_2-eq of direct GHGs.

Indirect GHGs are emitted at 558,525Gg; 7,942 Gg; 34,252 Gg and 2,563 Gg respectively for carbon monoxide (CO), nitrogen oxides (NO_X), volatile organic compounds (NMVOCs) and sulfur dioxide (SO_2).

The carbon intensity linked to the energy sector in Togo amounts to $1{,}797 \times 10^{-9}$ Gg CO_2-eq per GDP at the time when the standard of living was $ US319.222 per Capita. The analysis of the key sources gives five sub-categories, with Road Transport at 1,368 Gg of CO_2 emissions, representing a 55.4% contribution to total direct GHG emissions.

The overall inventory uncertainty is about ± 23.887% but higher on the N_2O, CH_4 and CO_2 estimates of biomass and fuel combustion in residential, commercial and road transport. It sets the level of CO_2 emissions at 2347 Gg. The relative difference between the sector and the reference method is 12.37% indicating consistency in the results.

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