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Assessment of CO_2 Emissions in the Petroleum Refining in Cameroon

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Abstract:

CO_2 has risen to the top of the list of the energy sector's environmental impacts and petroleum refining in particular, as the source of anthropogenic climate change. CO_2 emissions inventory from the petroleum refining sector in Cameroon reported in this article was conducted following the recommendations of the United Nations Framework Convention on Climate Change (UNFCCC); it concerns the unique refinery called the Cameroon national refinery (SONARA). This assessment is based on a bottom-up methodology of Tier 3. The combustibles data are obtained from the SONARA Technical Department during the period 2000-2008. The combustibles emission factors were determined after measurements following the American Society of Testing Materials standards within the SONARA laboratory. Hence, assessment results of CO_2 emissions at the SONARA show about 239 kilotons of CO_2 were rejected into the atmosphere. That is 5.56% the total CO_2 emissions in Cameroon for the year 2008. Moreover, the furnace of the atmospheric unit distillation is the combustion zone that emits the most CO_2. Emissions account for 45% of CO_2 emissions at the SONARA that is an average of 96.3 kilotons. This is the first CO_2 inventory for the petroleum refining category carried out in Cameroon; but we could not include fugitive emissions. However, the guidelines of the UNFCCC on GHG inventories state that countries shall report a national communication of anthropogenic emissions to the Conference of Parties, according to their capacities.

Keywords: Assessment, CO_2 emissions, petroleum refining, Cameroon

1.0 Introduction:

After the Rio Summit (Brazil) in 1992, 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 the concentration of greenhouse gases (GHGs) in the atmosphere to an extent that would prevent dangerous interference of human activities with the climatic system. The Cameroonian government for some years now has inventories of GHG in the energy, industrial processes, agriculture, land use and waste sectors. The first national communication on the GHG inventory in Cameroon was issued to the UNFCCC in 2005 (Ministry of Environment and Forests, 2005). In order to improve its performance and honor its commitment, the Cameroon second National Communication to the UNFCCC might be 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 submission of GHG inventories in the energy sector was made following the approach of the Tier 1 of the Intergovernmental Panel on Climate Change (IPCC, 1997) and the following emission sectors: the transports sector, the energy industries sector, the manufacturing and construction sector and the residential sector. However, the energy industries sector and the petroleum refining in particular have not been examined in details. Thus, to contribute to the work of the Cameroon government on the assessment of GHG emissions, the Environment Energy Technologies Laboratory (EETL) and the laboratory of SONARA through this article have done the assessment of CO_2 emissions in the refining process to SONARA. This study will permit future policies to deploy new technologies with low carbon emission for Cameroon's petroleum refining sector.

Emissions from the petroleum refining sector, classified by the IPCC (2006) code 1A1b cover all combustion activities required to support the refining of petroleum products including burning the site to generate electricity for own use. According to the guidelines of the IPCC (1997, 2006) and IPCC recommendations on good practice (2000), the calculation of CO_2 emissions in the petroleum refining sector is a calculation that should take into account the use of all fuels due to the petroleum refining sector. When technology is possible, the level of estimation is generally that of Tier 3 method. For the estimation of CO_2 emissions, we have used the bottom-up Tier 3 methodology of IPCC. The CO_2 emission factors are specific to Cameroon and are evaluated experimentally in the SONARA's laboratory using the American Society of Testing Materials standards (ASTM Standards, January 2010). Before estimating the CO_2 emissions, we present the overview of the SONARA in Section 2. In Section 3, the materials and methods adopted in the study are presented. Section 4 presents empirical results and discussion, and the last section concludes the study.

2.0 Overview of SONARA:

SONARA (Figure 1) is a mixed company specialised in crude oil refining. It was incorporated on the 7th of December 1976 (Metouck, 2006). It has a settlement agreement with the Cameroonian government since January 11, 1978. It was actually operational after its inauguration on the 16th of May 1981. Decree No. 2000/935/PM of the 13th November 2000 (Décret, 2000); establishes the conditions for conducting activities of the downstream petroleum sector. Part of the national market covers 20% share for the benefit of private operators and SONARA. Before the decree, SONARA covered the entire national market and today it covers at least 80% of the domestic market; it is important to note that SONARA covers 80% of domestic market with only about 45% of its total production as finished products. SONARA is a parastatal company with a capital of 23 billion CFA francs. This capital is held by many shareholders. The state of Cameroon is the major shareholder with 72.29% stake. Oil companies control about 27.71% of the capital including: Total Outre Mer (11.71%), Elf Aquitaine (8%) and Chevron Texaco (8%). The map in Figure 2 (Metouck, 2008) shows that SONARA is located in the South-west region of Cameroon at the foot of Mount Etinde on the shores of the Gulf of Guinea, latitude 4 ° 8'92 'North and longitude 9 ° 8'30 East (Louvet, 2008 ; Semen-Mvondo, 2004).

Fig. 1: View of SONARA

The SONARA's main objective is to refine crude oil into finished products to meet the needs of the Cameroonian market. The refining company conducts two key objectives, namely: the modernization of its installations and the expansion of the refinery in order to increase its production capacity. With an annual capacity processing of 2.1 million tons, SONARA plans on completing its work of modernization to increase its handling capacity to 3.5 million tons (Ondigui, 2009). It will be able to handle the totality of Cameroon's oil which today consists primarily of crude oil. In order to achieve its objectives, SONARA undertakes to implement a training plan and make efficient use of human resources, so as to intensify its policy of transferring knowledge and experience internally. It should be noted that SONARA covers only 10% of the domestic oil production (KOLE, EBOM), the rest is exported. These 10% are still mixed with light petroleum (mainly ALBA) before being refined. The success of its core aims and objectives will ensure the continuity of the SONARA and guarantee its energetic independence. The renown and competitiveness of SONARA would therefore increase in the sub region. Since June 2004, Health, Safety and Environment charter were established at the SONARA. This declaration is a commitment by all the staff of SONARA to protect oneself, colleagues, installations and preservation of the environment (Metouck, 2004).

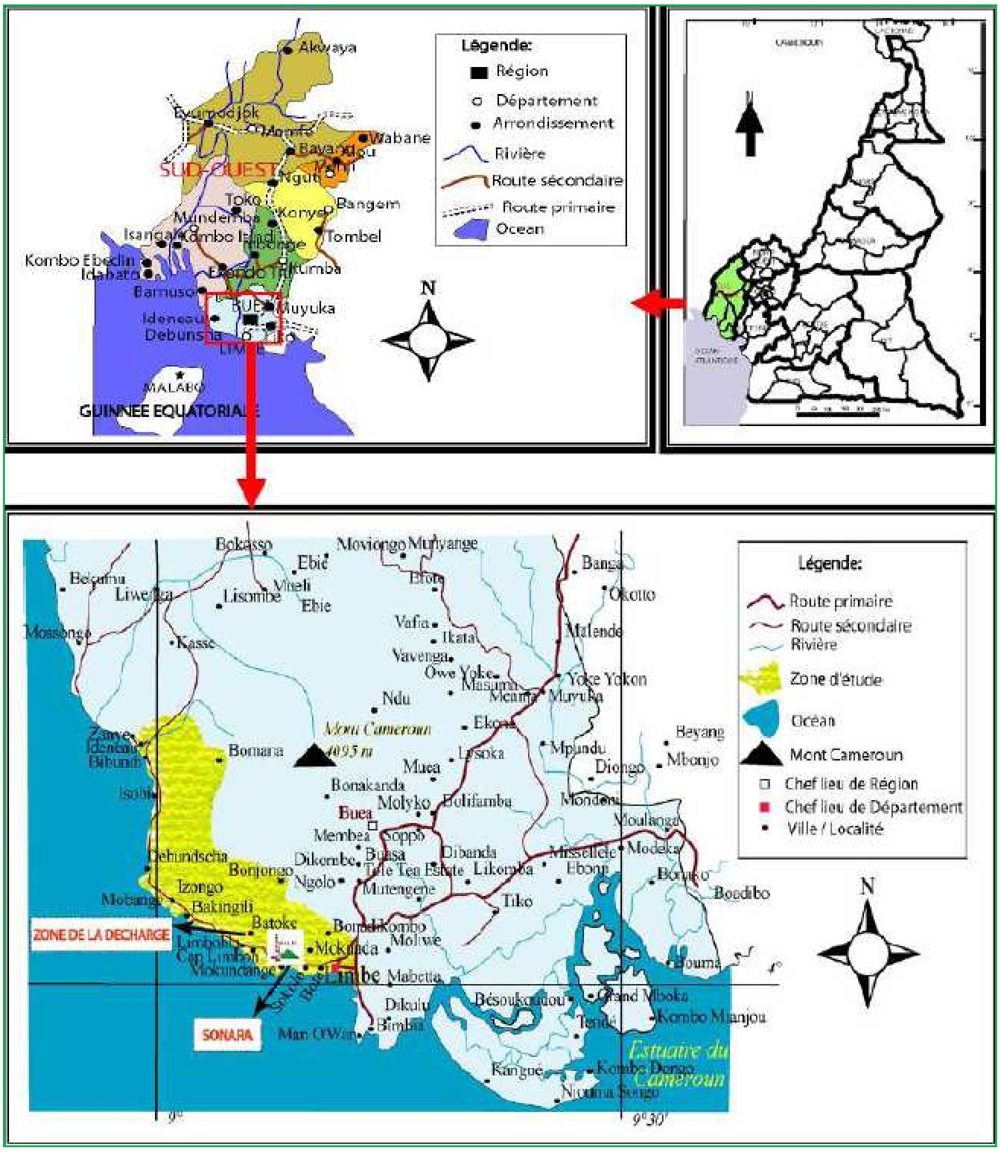

Fig. 2: Map location of SONARA

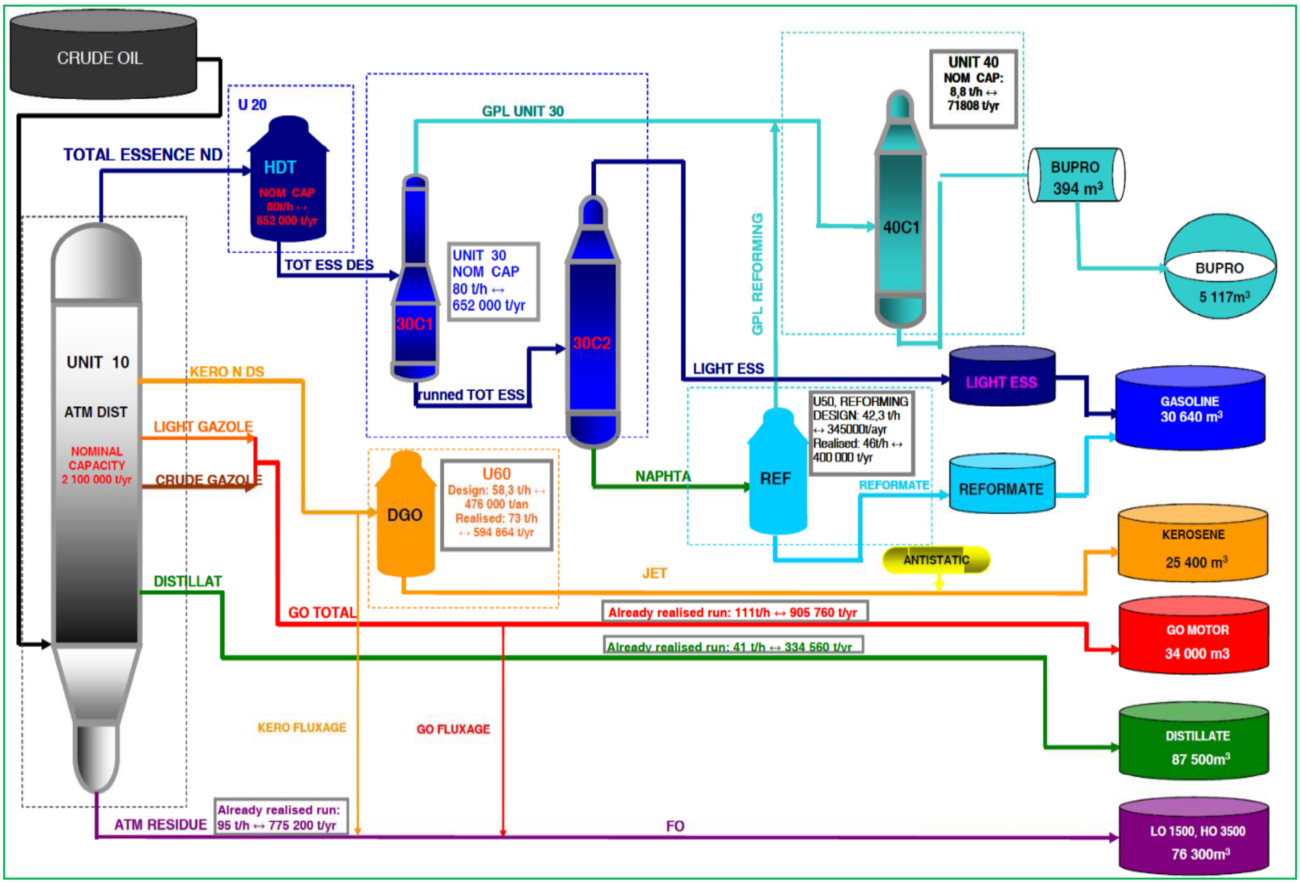

Fig. 3: Simplified diagram of the SONARA's production units

Crude oil is the raw material refined by SONARA. Its density varies between 0.79 tons/m^3 and 0.89 tons/m^3. The choice of crude oil for refining at the SONARA is done based on their structures, yields and the customer's demand in finished products. SONARA refines mainly light crude oil (the Arabian Light crude type). To refine its crude oil into various finished products, it has many production units as shown in Figure 3 (Metouck, 2007). The main ones are: the atmospheric distillation unit (U10), the hydrotreating unit of species (U20), the stabilization unit and splitting of species (U30), the processing unit of liquefied petroleum gas (U40), the catalytic reforming unit (U50) and the hydrodesulphurization unit of kerosene and diesel fuel (U60). SONARA refinery is of Hydroskyming or Topping Reforming type. It implements the atmospheric distillation and catalytic reforming method (SONARA, 1979).

3.0 Materials and Methods:

3.1 Combustion Zones of the Petroleum Refining:

The combustion zones of SONARA are precisely furnaces, boilers and electrical groups or sets for self-generation of electricity.

3.1.1 The furnaces:

The furnaces are appliances where fluid heating is done by convection using smoke and radiation from flames. These two phenomena are produced by the combustion of a liquid or gaseous fuel. Generally, furnaces mainly include the following principal parts (Trambouze, 1999):

1) An area of radiation, consisting essentially of a combustion chamber in which the tubes are arranged in coils. The heated fluid circulates inside the tube's bundle. Heat transfer occurs mainly by radiation.

2) In order to recover the sensible heat from the smoke, the later circulates at high speeds through a tube bundle whose structure is well suited to capture the smoke. The exchange made at this level is mainly by convection. This area is therefore a qualified one for convection.
3) A chimney used to vent smoke.

There are many provisions of the tubes in the radiation and convection areas. From one area to another, one can distinguish several types of furnaces: the vertical cylindrical furnaces, furnaces called boxes with vertical tubes, furnaces with horizontal tubes called cabins, furnaces with radiant wall heating, the so-called dual heating furnaces and many others. At SONARA, there are essentially two types of furnaces: the vertical cylindrical furnaces and the cabins furnaces with horizontal tubes. The cabins furnaces with horizontal tubes are made of furnace of unit 10 (10F1) and four furnaces of unit 50 (50F1, 50F2, 50F3 and 50F4) while the vertical cylindrical furnaces are made of furnaces of unit 20 (20F1) and unit 60 (60F1) (DQSEI, 1979, 1991 and 2009). SONARA assimilates combustion in these furnaces to complete combustion. According to visual analysis of these furnaces, flames are characterized by a light yellowish colour that turns blue and a weak presence of coke on the walls of these furnaces.

Furnace 10F1 (Figure 4.a) ensures the vaporization of crude oil in 10C1. It is a mixed combustion furnace. It operates with either fuel oil or with fuel gas or simultaneously with both. Furnace 10F1 has 24 burners with 1.51 million kcal / hr (hour) released as heat energy. The burners are all JOHN ZINK brand. Furnaces 10F1, 20F1 and 60F1 are from LUMMUS industries; and four furnaces of the U50 are from the FOSTER WHEELER industries. The 10F1 operates more with fuel oil with an average monthly consumption of 1,263 tons, than with fuel gas which has an average monthly consumption of 1,105 tons. This variation in 10F1 is due to the chemical characteristics of crude oil and the fluctuation in the amount of fuel gas consumed by the other furnaces. Crude oil refined at SONARA generally has a higher amount of fuel gas than fuel oil.

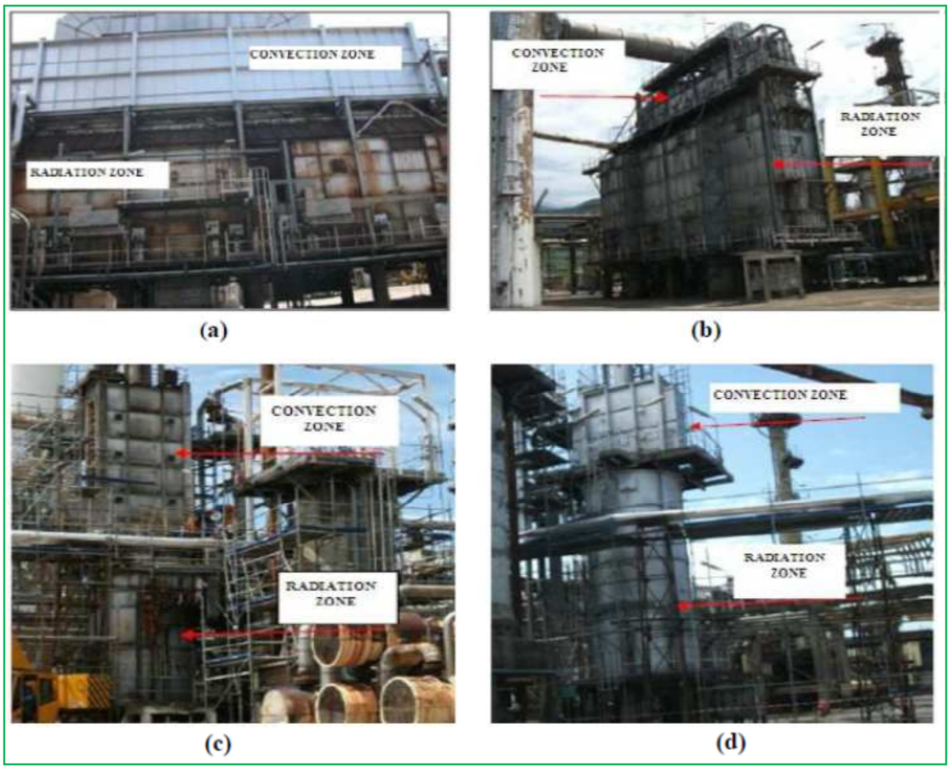

Fig. 4: Furnaces of SONARA

The four furnaces of U50 (Figure 4.b) run only on fuel gas and have a total amount of 24 burners. Furnace 50F1 has nine burners and releases 1,330,000 kcal / hr as heat energy, furnace 50F2 has six burners and releases 1,380,000 kcal / hr, the furnace 50F3 has six burners and a normal release of 1,158,000 kcal / hr and furnace 50F4 has three burners and releases 1,158,000 kcal / hr as heat energy as well. The four furnaces of U50 are supplied by the same pump 50P1 (measured by one meter). The average monthly fuel gas consumption of the four furnaces of unit 50 is 1011 tons. Furnaces 20F1 (Figure 4.c) and 60F1 (Figure 4.d) are identical and have the same combustion characteristics. These two furnaces have three burners each and they operate only with fuel gases and release 1,017,000 kcal / hr as heat energy, with an average monthly consumption of 123 tons of Fuel gas for 20F1 and 121 tons for 60F1. Since the 20F1 and 60F1 have the same characteristics, we will look at the sum of their consumption. The total average fuel gas consumption is 244 tons per month.

3.1.2 Boilers:

The refinery boilers are designed to produce steam at high pressure and temperature in the best conditions of safety and performance from the combustion of liquid or gaseous combustibles (IFP Training, 2006). SONARA has two identical boilers (Figure 5) with water pipe, manufactured by Lardet-Babcock industries. Each boiler has a temperature of superheated steam of 300°C for a minimum pressure of 17 bars. These boilers consist of a combustion chamber; heat exchangers made up of bundles of tubes through which water and steam flow; a circuit comprising an air blower and possibly an air heater to the burners and a circuit of smoke possibly extracted by an exhaust fan in the chimney flue. The boilers operate at full load either on burning fuel oil alone, on combustion of fuel gas alone or with the two combustible. It is important to mention that the burners of boilers are not visible like those of furnaces. To produce a sufficient amount of steam to run the refinery, the SONARA needs to consume a significant amount of combustible. The average monthly fuel gas and fuel oil consumption were 416 tons and 483 tons during the period 2000 – 2008 respectively.

3.1.3 The Thermoelectric Power Station:

The treaties signed by SONARA with the Cameroonian government stipulate that a portion of the electrical energy consumed by the refinery should be provided by the company in charge of electricity distribution in Cameroon. Taking part of its energy from the company in charge of electricity distribution has a positive aspect towards the mitigation of GHGs. This hinders SONARA from emitting GHGs by producing all of its electrical energy. The other part of the electrical energy consumed by SONARA is self provided by its thermoelectric power station. SONARA has three electric diesel generators, (Figure 6) each with a maximum power of 4MW built by Alsthom Atlantique industries (SONARA Motor, 2010). These machines operate at a normal speed of 1,000 revolutions per minute with an inlet pressure of diesel of 2.5 bars and outcoming temperatures of about 485 ° C. Diesel is the only fuel consumed in the SONARA for self electrical generation. They are supplied by the same pump. The amount of fuel from the pump is measured by a single meter. The diesel consumption is between 600 and 800 tons with an average monthly consumption of 687 tons.

Fig. 5: Water-tube boiler of SONARA

3.2 Assessment Methodology of CO_2 Emissions:

Climate changes are alterations that occur during long-term weather patterns. They are caused by natural phenomena and are accelerated by human activities which modify the chemical composition of the atmosphere by increasing the accumulation of greenhouse gases (GHGs). These greenhouse gases trap heat and reflect it to the Earth's surface. Human activities generate three main long life GHGs emissions: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Atmospheric concentrations of greenhouse gases have increased substantially since 1750. The Earth's atmospheric concentration in CO_2 has risen from about 280 parts per million in volume (ppmv) during the industrial revolution to 379 ppmv in 2005. On the other hand, the Earth's atmospheric concentration in CH_4 has changed from about 715 parts per billion in volume (ppbv) during the industrial revolution to 1732 ppb in the early 1990s. This has reached 1774 ppb in 2005. The Earth's atmospheric concentration of N_2O has increased from 270 ppb during the industrial revolution to 319 ppb in 2005 (IPCC, 2007). Moreover, between 1970 and 2004, GHG emissions globally due to human activities have grown by about 70%. These trends can be explained largely by the use of fossil combustibles. The main objective of the United Nations Framework Convention on Climate Change (UNFCCC) is to stabilize atmospheric GHG concentrations at a level that would prevent dangerous interference with the climate system. 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. The GWP of a greenhouse gas counts for both the instantaneous radiative forcing due to increased concentration and lifetime of the GHG concern. In our study, the GWP for CO_2 is 1, that of CH_4 is 21 and that of N_2O is 310 time the GWP for CO_2 (IPCC WG1, 2007).

Fig. 6: SONARA's generators

At the SONARA, just as in any other oil refinery, crude oil is transformed into many products. In order to make this transformation possible, part of the energy content of products obtained from crude oil is used in the refinery (Figure 7) (IPCC, 2006). In the IPCC Guidelines (IPCC, 1997, 2006) and the IPCC Good Practice Guidance (IPCC, 2000), the methodological approach is simple and general; it is to combine information on the extent of human activities (activity data or AD) with the coefficients that quantify emissions per unit activity. These are called emission factors (EF). Therefore, the basic equation is

$$\boldsymbol{Emissions = AD \times EF} \qquad (\mathbf{1})$$

In the remaining work, we collect the AD on three combustibles (Fuel oil, Fuel gas and diesel) necessary for the proper functioning of the refinery and we also discuss the relevance of EF for use in the refinery (McCann, 2000). The emission factors are calculated from experimental methods of analysis and application found in the SONARA's laboratory in 2010. Analysis of the combustibles was conducted in the SONARA's laboratory according to a methodology described in the ASTM standards for liquid products; chromatographic analysis was also carried out for the gaseous products.

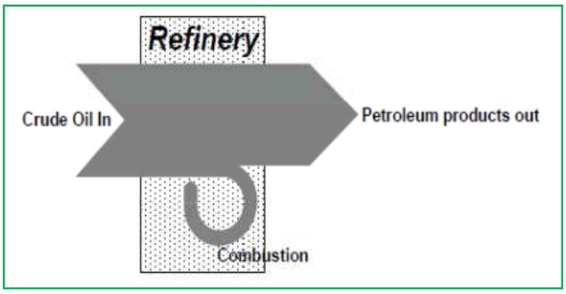

Fig.7: A refinery uses energy to transform crude oil into petroleum products

SONARA has a laboratory that meets accreditation standards NF 17025 (French standard) in the ISO/CEI and rules for implementing Cofrac (French committee for accreditation) under the number 1-1154. The results of our analysis presented in Table 1 consist of average density values, lower heating value (LHV) and CO_2 emission factors related to the petroleum products manufactured in the oil refinery in Cameroon. The results of the CO_2 emission factors obtained in Table 1 are included in the confidence interval of 95% of the IPCC.

Knowing the emission factors used, as well as the activity data, equation 2 allows for an accurate calculation of CO_2 emissions from the SONARA refinery.

$$\boldsymbol{Emissions} = \sum_i (\boldsymbol{AD_i} \times \boldsymbol{density_i} \times \boldsymbol{LHV_i})(\boldsymbol{0.99EF_{i,co2}}) \qquad (2)$$

Table 1: Characteristics and factors of CO_2 emission from combustibles

Type of combustible	Density at 15 ° C in Mg/m^3	LHV in MJ/kg (TJ/Gg)	Carbon content in kg/GJ	Fraction of oxidized carbon (1)	CO_2 emission factor in kg/TJ
Super (Gasoline)	0.768	43.668	19.582	0.99	71082.097
Jet A1	0.818	43.074	20.081	0.99	72894.115
Kerosene	0.818	43.074	20.081	0.99	72894.115
Diesel	0.862	42.559	20.397	0.99	74040.605
OL- 1500	0.943	41.392	21.173	0.99	76858.620
HO-3500	0.948	41.374	21.247	0.99	77128.068
LPG	0.567	45.850	17.200 (3)	0.99	62436.000
Fuel gas	0.241	63.201 (2)	15.700 (3)	0.99	56991.000
Fuel oil	0.954	41.305	21.277	0.99	77234.940

(1) Revised 1996 IPCC Guidelines, oxidation factor.
(2) LHV of fuel gas is not part of the upper and lower limits of reliable intervals of 95% of the IPCC, this gas is not treated rigorously as other combustibles sold for it is consumed directly and solely in the process of refining at the SONARA. It has on average more than 82% H by volume according to chromatographic analysis.
(3) Default carbon content of LPG and fuel gas from the IPCC Guidelines 2006 (these amounts are used due to the lack of equipment for analysis in SONARA's laboratory).

4.0 Empirical Results and Discussion:

The results of CO_2 emissions in kilotons (kt) in Cameroon petroleum refining sector for the period 2000-2008 is shown in Figure 8. The furnace 10F1 of unit 10 is the largest area of CO_2 emissions from the combustion zones of SONARA.

It accounts for approximately 45% of CO_2 emissions throughout the refinery averagely per annum (Figure 9). The quantity of CO_2 emitted by the 10F1 is found between the statistical maximum and minimum value of about 120 kt and 79 kt respectively (Table 2). Its annual average growth rate is 4.25%. The four furnaces of unit 50 hold the second place with 21% of CO_2 emissions from 2000 to 2008. Its annual average growth rate is 4.32%. Boilers and generators have 17% and 12% share of CO_2 emissions averagely per year from combustion zones respectively. The emissions curves from boilers and generators have maximum emissions peak in 2004 of about 52 kt and 30 kt respectively. The average annual growth rate of CO_2 emissions is 0.41% for boilers and 0.01% for generators. It contrasts to the emission curve of furnace 20F1, 60F1 evolutionary curve has a remarkable increase of CO_2 emissions by 52.6% from 2004-2005. The amount of CO_2 emissions from furnaces 20F1 and 60F1 is almost identical, their average annual emissions is about 5.42 and 5.22 kt respectively. Their average annual growth rate is 1.65% for emissions generated by the furnace 20F1 and 1.96% for the furnace 60F1. The furnaces 20F1 of unit 20 and 60F1 of unit 60 are at the bottom with 3% and 2% share of emissions respectively from the combustion zones of SONARA.

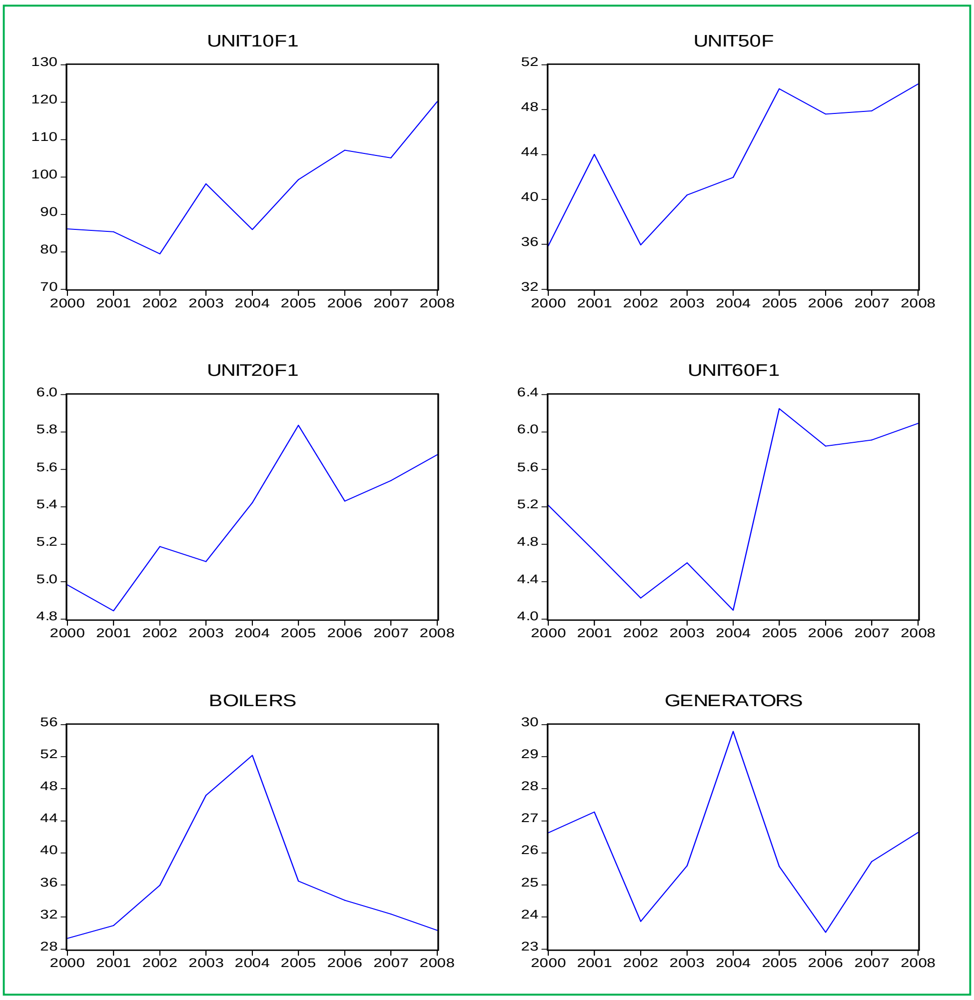

Fig.8 Trends in CO_2 emissions in kt from 2000-2008

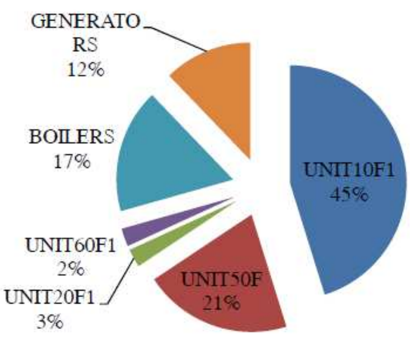

Fig. 9: Annual average percentage of CO_2 emissions

Table 3 shows the growth of CO_2 emissions from the refinery in the combustion zones from 2000 to 2008. It shows clearly that the increase of 40.3% of emissions in furnaces of unit 50 during the eight years is well above the boiler emissions (3.3%), generators (0.1%), furnaces 20F1 (14.0%) and 60F1 (16.8%). It is almost identical to the increase in emissions for the furnace 10F1 (39.5%). Finally, the CO_2 emissions of the refinery increase of 27.1% from 2000 to 2008. Trends of CO_2 emissions are summarized graphically in Figure 10.

Table 2: Statistical CO_2 emissions

	UNIT 10F1	UNIT 50F	UNIT 20F1	UNIT 60F1	BOILERS	GENERATORS
Mean (kt)	96.31655	43.75810	5.336676	5.219611	36.54525	26.07088
Median (kt)	98.15298	44.02243	5.422183	5.216688	34.10075	25.73395
Maximum (kt)	120.1365	50.28498	5.835734	6.249742	52.14056	29.79155
Minimum (kt)	79.49902	35.85094	4.845355	4.095478	29.37194	23.52963
Std. Dev.	13.18466	5.585130	0.328636	0.835327	7.917232	1.864983
Sum (kt)	866.8490	393.8229	48.03008	46.97650	328.9073	234.6379
Sum Sq. Dev. (kt)	1390.682	249.5494	0.864014	5.582170	501.4605	27.82529
Observations	9	9	9	9	9	9

Table 3: Growth in CO_2 emissions as a percentage (%) since 2000 by combustion zone

Years	2000	2001	2002	2003	2004	2005	2006	2007	2008
UNIT 10F1	-	-0.9	-7.7	14.0	-0.1	15.3	24.5	22.1	39.5
UNIT 50F	-	22.8	0.3	12.7	17.1	39.1	32.8	33.6	40.3
UNIT 20F1	-	-2.7	4.1	2.5	8.8	17.1	9.0	11.2	14.0
UNIT 60F1	-	-9.3	-19.0	-11.8	-21.5	19.8	12.1	13.4	16.8
BOILERS	-	5.3	22.4	60.7	77.5	24.2	16.1	10.2	3.3
GENERATORS	-	2.5	-10.4	-3.8	11.9	-3.9	-11.6	-3.3	0.1
REFINERY	-	4.8	-1.8	17.5	16.6	18.7	18.9	18.3	27.1

The evolution of total CO_2 emissions due to the refining of crude oil has a growing trend. We should note that in 2008, SONARA rejected into the atmosphere about 239 kt of CO_2 emissions (Table 4), that is, an increase of 27.13% relative to 2000. Table 4 equally shows the global impacts of CO_2 emissions in terms of indicators. It shows clearly that CO_2 emissions per Gross Domestic Product and CO_2 emissions per total fuel consumption in SONARA decrease from 2000 to 2008, that is an increase rate of -3.59% and -6.63% respectively. On the other hand, CO_2 emissions per inhabitant have increased by 5.80% during the same period. The total CO_2 emissions in Cameroon are obtained from the International Energy Agency (IEA, 2011). The total fuel consumption is obtained from SONARA's statistics (SONARA, 2009). The population data come from the National Institute of Statistics of Cameroon (NIS, 2010). The Gross Domestic Product data are gotten from the World Bank (World Bank, 2011). CO_2 emissions in petroleum refining are less than 10% of the total CO_2 emissions. Petroleum refining sector related emissions account for 6.71% in 2000 and 5.56% in 2008 of the total fraction of CO_2 emissions. Overall, the fraction CO_2 emissions in petroleum refining sector decreases in the total CO_2 emissions during the study period in Cameroon. Thus, CO_2 emissions in the petroleum refining category in Cameroon are low, compared to those in developed countries. In 2008 for example, Canada emitted 16,000 kt of CO_2 (NIR, 2010) against 239 kt for Cameroon that is approximately 67% greater than that of the latter. This result clearly shows that Cameroon is ranked as a Non-Annex 1 party.

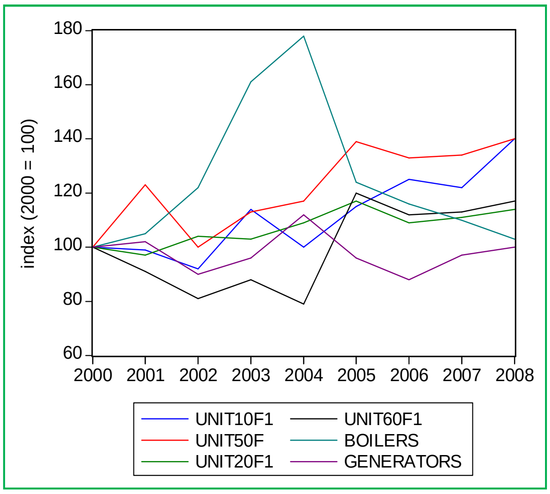

Fig. 10: Trend indicators of CO_2 emissions at the SONARA from 2000 to 2008

Table 4: Refinery CO_2 emissions impacts

Years	2000	2001	2002	2003	2004	2005	2006	2007	2008
CO_2 emissions of SONARA (kt)	188	197	185	221	219	223	224	223	239
Average annual change since 2000 (%)	-	4.79	-1.60	17.55	16.49	18.62	19.15	18.62	27.13
Change over previous year (%)	-	4.79	-6.09	19.46	-0.90	1.83	0.45	-0.45	7.17
GDP in billion 2000 US dollars ($)*	10.08	10.53	10.95	12.91	11.39	11.82	12.09	12.48	13.29
CO_2 emissions per GDP (kt/billion US$)	18.65	18.71	16.89	17.12	19.23	18.87	18.53	17.87	17.98
Average annual change since 2000 (%)	-	0.32	-9.44	-8.20	3.11	1.18	-0.64	-4.18	-3.59
Population (10^6 inhabitants)**	15.36	15.79	16.23	16.64	17.06	17.12	17.55	17.99	18.45
CO_2 emissions per inhabitant (kt/10^6 inhabitant)	12.24	12.48	10.95	13.28	12.83	13.03	12.76	12.40	12.95
Average annual change since 2000 (%)	-	1.96	-10.54	8.50	4.82	6.45	4.25	1.31	5.80
Total fuel consumption in SONARA (ktoe)***	30.43	31.11	28.50	39.38	38.48	36.59	38.51	37.66	41.40
CO_2 emissions per total fuel consumption (kt/ktoe)	6.18	6.33	6.49	5.61	5.69	6.09	5.82	5.92	5.77
Average annual change since 2000 (%)	-	2.43	5.02	-9.22	-7.93	-1.46	-5.83	-4.21	-6.63
Total CO_2 emissions in Cameroon (kt)****	2800	-	-	-	-	2900	-	4100	4300
SONARA's Fraction (%)	6.71	-	-	-	-	7.69	-	5.44	5.56
CO_2 emissions of Canada's refinery (kt)*****	14000	16000	19000	19000	18000	17000	16000	18000	16000
CO_2 emissions of Canada's refinery/ CO_2 emissions of SONARA	74.41	81.15	102.88	85.95	82.04	76.12	71.52	80.87	66.90

* Represents the Cameroon's Gross Domestic Product (GDP) obtained from the world data bank.
** Represents population obtained from the National Institute of Statistics of Cameroon.
*** Represents total fuel consumed for the functioning of SONARA, the data are obtained from SONARA.
**** Represents the data obtained from the International Energy Agency.
***** Represents the data obtained from the National Inventory Report; Canada.

5.0 Conclusion:

The consumption of finished refined petroleum products in the national market plays an important role for the growth of CO_2 emissions attributable to stationary combustion of the SONARA. Taking into account the confidentiality of the total production data of refined petroleum products at SONARA, our conclusion is only based on the assessment of the CO_2 emissions during the refining of petroleum products from 2000 to 2008. It attributes the increase of CO_2 emissions to a combination of several factors such as growth in Cameroon: the evolution of the vehicle fleet, the construction of several tarred roads, increased rail way, air and sea traffic, the substitution of wood energy consumption by modern fuel in households, the creation of manufacturing and implementation of a thermal emergency program (increased supply power through the creation of new thermal power plant). All these factors increase the demand of petroleum products. To satisfy its consumers, SONARA increases its production of petroleum products and consequently CO_2 emissions. As a Non-Annex 1 party, Cameroon's government has the right to insure favorable conditions to its development, which inevitably requires her to invest heavily in the promotion of alternative low CO_2 emissions refinery by developing scientific research in the Cameroon petroleum refining sector. Cameroon environmental strategy aims at replacing the consumption of fuel oil and diesel with refinery gas in the petroleum refining sector. Cameroon's rationale for such a conversion is major: emissions into the atmosphere from conventional burning of fossil fuel must be reduced to prevent environmental damage; and alternative fuel must be used to enable sustainable development. The results of this study suggest for future policy implementation to support sustainable refinery gas and high efficient refinery, the deployment of low-carbon technology for refineries and both rejuvenation and extension of SONARA. Cameroon economy will have to make a transition from a fossil fuel-based to a renewable fuel-based economy. As such, Cameroon is willing to contribute to the world effort to fight against climate change. Finally, this study does not only contribute to ameliorate the Cameroon national communications on the GHG inventory to the UNFCCC, but also the achievement of the Clean Development Mechanism (CDM).

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