

# I. Inventory of Greenhouse Gases

## Summary

The objective of the inventory of GHGs was to identify the principal sources and to establish estimates of GHG emission from different sectors. The main GHG and precursors emitted in Ethiopia for the year 1990 are CO<sub>2</sub> (16297 Gg), CO (7611 Gg), CH<sub>4</sub> (1586 Gg), and NO<sub>x</sub> (171 Gg) and N<sub>2</sub>O (4.7 Gg). The results of the inventory of GHGs suggested that land use changes and forestry is principal emission sources in Ethiopia while Agriculture and energy are second and third respectively. Changes in land use and forestry are principally related to the expansion of agricultural activities. Emission in energy sector are related to the combustion of products originating in petroleum and traditional biomass burning to meet the energy demand, particularly in the household and transportation sub-sector. CH<sub>4</sub> emission from enteric fermentation of herbivorous animals is highly significant as the country's livestock population is relatively large.

## Methods

In this study GHG emission inventory from the following sources were considered using the IPCC recommended methods.

1. Energy consumption, either traditional or modern;
2. Greenhouse gases emission from bagasse (stationary combustion);
3. Agriculture; emissions form livestock, field burning of agriculture
4. Land use change and forestry; with special attention given to emission
5. Waste:emissions form landfills (municipal solid waste) and liquid
6. Industrial processes: like emissions from cement factory.

During the course of this inventory program, the following various gases annually emitted from different source are quantified

### A. Energy Module

#### A.1 Actual Carbondioxide Emissions from Fossil Fuel

The main reason why fossil fuels are regarded as an important source of CO<sub>2</sub> emission is that the transportation sector in whole and many industries in Ethiopia are highly dependent on fossil fuel/ petroleum products for their energy supply.

In other words, although Ethiopia is one of the least developed countries, it uses fossil fuels for operating various economic sectors. Due to this fact the CO<sub>2</sub> released from petroleum products is not negligible.

Fossil fuels which their annual CO<sub>2</sub> release is determined are:

**I Primary Fuel, Crude oil**

**II Secondary Fuels**

- a) Gasoline
- b) Kerosene
- c) Jet kerosene
- d) Residual fuel oil
- e) Liquid petroleum gas
- f) Diesel
- g) Bitumen
- h) Lubricants
- i) Banker Fuel oil; Actually not included in the total national emission, Since the emission could affect territories out side of the country.

The actual CO<sub>2</sub> emission from each fossil fuel is obtained by multiplying the actual carbon emission with the molecular weight of carbondioxide to carbon.

In order to obtain the total annual emission from all fossil fuel types, the annual emission from crude oil consumption is added to the total annual emission from secondary fossil fuels.

## **A.2 GHG Emission from Traditional Biomass Burned for Energy (Off-site Burning)**

In the IPCC worksheet manual, method of Emission calculations for CH<sub>4</sub>, CO, N<sub>2</sub>O and NO<sub>x</sub> from biomass fuels are clearly presented. It is believed that the above gases released from biomass energy use is high as the country is highly dependent on biomass to meet its energy demand, particularly of the household sector. The main traditional biomass fuels burned for energy in Ethiopia are: Wood, Agricultural residues, charcoal, and Dung. *Carbondioxide emission from biomass fuels ( for energy use ) has been treated as zero, because it is assumed that biomass fuelwood growth is sustainable in*

*the country. Therefore the net emission will be zero. However, this needs further investigation.*

## **B. Greenhouse Gas Emission from Stationary Combustion.**

In this section special attention has been given to bagasse use as fuel in industrial boilers. Because, the process residue that provides the greatest source of energy in industry is bagasse, from sugar refining. The use of other process residues like agricultural waste in boilers is not considered important as the number and capacity of the industries which use this energy source are limited. In this module, only CO and NO<sub>x</sub> emissions are calculated. It was not possible to compute other gases, because emission factors for bagasse-fired boilers for other gases has not been provided.

## **C. Agriculture Module.**

IPCC has recommended countries to look at greenhouse gas emissions from rice cultivation. However, Ethiopia is a non-rice producing country. In other words, there is no emission from rice field flooding. Therefore, in the agricultural module, only livestock and manure management, savanna burning and open burning of agricultural residues are considered as potential emission sources in Ethiopia.

Ethiopia ranks first in animal population in Africa and 10<sup>th</sup> in the world. CH<sub>4</sub> emissions from ruminant( e.g. cattle, sheep) and non-ruminant(e.g. horse, ass) animals due to enteric fermentation and manure management is quantified. No attempt was made to calculate CH<sub>4</sub> emission from wild animals because of the lack of animal statistics.

Agricultural residues have various uses in Ethiopia. In order to prepare the land for the next growing cycle, the residues left in the field are usually burned in open conditions. Emissions of non-CO<sub>2</sub> trace gases (CH<sub>4</sub>, CO, N<sub>2</sub>O, NO<sub>x</sub>) for which local statistics of the crop or residue is available are computed.

It is believed that savanna burning in Ethiopia contributes a significant amount of trace gas emissions to the national total non-CO<sub>2</sub> trace gas emission. CO<sub>2</sub> emission from this source area is not considered important as the emission released could be reabsorbed during the next vegetation regrowth period. In other words, since in savanna areas a continuous grass regrowth

between burning cycles occur, the net carbondioxide emission is considered to be zero.

#### **D. Land use change and Forestry module.**

Calculation of GHG emissions from land use practices and forestry is the most difficult area. It requires a lot of information than any other emission source sectors.

In Ethiopia, there is a scarcity of updated statistics especially on types of forests available and annual area cleared. Because of this reason an attempt has been made to obtain information from various documents produced by government institutions and international organizations. Based on the obtained information, natural forest areas cleared annually from 1989/90-1992/93 including emissions for these years have been computed. GHG emissions quantified in this module are:

- a)CO<sub>2</sub> release from burning of above ground biomass on-site and off-site;
- b)Non-CO<sub>2</sub> emissions from on-site burning of cleared forests.

Forest resource information obtained from the Ethiopian Energy Authority for 1981 and deforestation rate from ECA documents (African compendium of environmental statistics, 1993 ) have been used as a base of estimating natural forest area cleared annually.

Actually, to obtain complete information of forest type as classified in IPCC document was very difficult. Therefore, some modification has been made on the IPCC worksheet paper, in order to fit the format category to Ethiopia's forest classification. Based on the estimated area cleared annually, CO<sub>2</sub> emission for 1989/90-1992/93 has been computed.

Total annual CH<sub>4</sub>, CO, N<sub>2</sub>O, and NO<sub>x</sub> emissions have been computed using the carbon released from on-site and off-site burning of each forest type. Similar to the carbondioxide release, emissions of the above trace gases for 1989/90-1992/93 were calculated.

#### **E. Waste Module.**

In this module, methane gas emissions from Municipal solid & liquid waste, and Industrial liquid waste for Addis Ababa have been inventoried. There is no statistics on quantity of liquid waste for other towns of the country. However, CH<sub>4</sub> emission from solid waste of other towns were calculated, using the urban population figure for 1989/90-1992/93.

Methane emissions from Addis Ababa city municipal solid waste for the year 1989/90-1992/93 have been calculated based on the amount of solid waste collected annually from the city. As mentioned above an attempt has been made to quantify also CH<sub>4</sub> emissions from other urban solid waste based on the population figures.

In this section methane emissions from Addis Ababa municipal liquid waste only has been determined. Because, statistics on population who uses toilets and daily BOD<sub>5</sub> generation rate of other urban centers was not available.

The methane emission from industrial liquid waste was calculated based on the annual waste water out flow used in the process of production. The calculation does not cover emissions from liquid waste of all industries in the country, because of the lack of information on production potential and other statistics. In this section CH<sub>4</sub> emitted from canneries, beer, wine, meat packing, oil and grease, soft drink and other food (eg. bread ) for the year 1989/90-1992/93 has been computed as there are statistics on production capacity.

#### **F. Industrial Process Module.**

In This module due attention has been given to quantify CO<sub>2</sub> emission from cement plant. There is no local statistics on production potential of other factories that release CO<sub>2</sub>.

Carbondioxide Emission from Addis Ababa and Mugar cement factories for the years 1989/90-1992/93 has been inventoried. The yearly production figure of these factories is available and well compiled. The emission form Dire-Dawa cement factory is ignored as the factory is not operating since the end of 1991.

### **Results and Discussion**

#### **Carbondioxide (CO<sub>2</sub>)**



	Biomass	.54		.99		09	
	Cement	158.3		205.9		129.98	187.98
		2					
	<b>TOTAL</b>	<b>2948.29</b>	<b>13960.86</b>	<b>1723.38</b>	<b>13802.89</b>	<b>2948.29</b>	<b>13523.07</b>
							<b>1723.38</b>
							<b>13364.84</b>
CO	Fuel Wood	1888.59		1958.85		2007.91	2057.49
	Agri-re.(E)	165.39		169.8		174.27	178.91
	Dung	178.28		182.97		187.78	192.72
	Charcoal Pr.	102.99		116.89		114.6	112.97
	Charcoal Co.	24.18		27.45		26.9	26.53
	Forest Burn.	527.01		519.16		511.37	503.12
	Savanna	4491.17		4333.98		4182.29	4035.91
	Agr-re (F)	166.48		188.12		199.18	211.83
	Bagass	7.93		8.09		8.26	8.43
	<b>TOTAL</b>	<b>2533.84</b>	<b>5018.18</b>	<b>2652.17</b>	<b>4853.14</b>	<b>2718.9</b>	<b>4693.66</b>
							<b>2788.88</b>
							<b>4539.03</b>
CH <sub>4</sub>	Fuel Wood	215.84		223.87		229.48	235.14
	Agri-re.(E)	7.88		8.09		8.3	8.52
	Dung	28.86		29.62		30.4	31.2
	Charcoal Pr.	61.8		70.13		68.76	67.79
	Charcoal Co.	0.32		0.37		0.36	0.35
	Forest Burn.	60.23		59.33		58.44	14.5
	Savanna	171.09		165.1		159.33	153.75
	Livestock	957.59		990.58		980.36	984.81
	Agr-re (F)	7.93		8.96		9.48	10.09
	Landfill (AA)	6.72		5		4.8	14.29

	Landf. (ext. AA)	20.59		21.35		22.12		68.2
	Waste W. (AA)	1.05		1.08		1.12		1.15
	Fugitive	24.52		16.87		10.96		18.36
	<b>TOTAL</b>	<b>1305.79</b>	<b>258.63</b>	<b>1349.57</b>	<b>250.78</b>	<b>1339.22</b>	<b>244.69</b>	<b>1357.41</b> <b>250.74</b>
NO <sub>x</sub>	Fuel Wood	53.63		55.63		57.02		58.43
	Agri-re. (E)	7.05		7.23		7.42		7.62
	Dung	5.06		5.2		5.33		5.47
	Charcoal Pr.	2.92		3.32		3.25		3.21
	Charcoal Co.	0.69		0.78		0.76		0.75
	Forest Bur.	14.97		14.74		14.52		14.29
	Savanna	75.89		73.24		71.26		68.2
	Agr-re (F)	8.18		9.23		9.84		10.4
	Bagass	0.41		0.42		0.43		0.44
	<b>TOTAL</b>	<b>77.94</b>	<b>90.86</b>	<b>81.81</b>	<b>87.98</b>	<b>84.05</b>	<b>85.78</b>	<b>86.32</b>
N <sub>2</sub> O	Fuel Wood	1.48		1.54		1.58		1.62
	Agri-re. (E)	0.19		0.2		0.21		0.21
	Dung	0.14		0.14		0.15		0.15
	Charcoal Pr.	0.08		0.09		0.09		0.09
	Charcoal Co.	0.02		0.02		0.02		0.02
	Forest Bur.	0.41		0.41		0.4		0.39
	Savanna	2.12		2.04		1.97		1.9
	Agr-re (F)	0.23		0.26		0.27		0.29
	<b>TOTAL</b>	<b>2.14</b>	<b>2.53</b>	<b>2.25</b>	<b>2.45</b>	<b>2.32</b>	<b>2.37</b>	<b>2.38</b>

Note: - 1989/90, 1990/91, 1991/92, and 1992/93 are interms of Ethiopian fiscal year ,that starts in the beginnings of July of the former year and ends towards the end of June of the latter. This calendar is used as some of the data are compiled in Ethiopian calendar.

EMIS SION	SECTOR	SOURCE	1990	1991	1992
CO <sub>2</sub>	Energy	Fossil Fuel	2335.84	2335.65	2335.84
	Lan.&For.	Forest Burning	13802.54	13596.99	13393.09
	Industry	Cement	158.32	205.9	129.98
	<b>Total</b>		<b>16296.7</b>	<b>16138.54</b>	<b>15858.91</b>
CO	Agricul.	Savannah	4491.17	4333.98	4182.29
	Energy	Bagasse	8.01	8.18	8.35
		Charcoal	135.76	142.93	140.51
		Agri-Res.	167.6	172.04	176.59
		Dung	180.63	185.38	190.25
		Fuel Wood	1923.72	1983.38	2032.7
	Lan.&For.	Agri-Res.	177.3	193.65	205.51
		Forest Burning	527.01	519.16	511.37
<b>Total</b>		<b>7611.2</b>	<b>7538.7</b>	<b>7447.57</b>	
CH <sub>4</sub>	Agricul.	Savannah	171.09	165.1	159.33
		Livestock	974.09	985.47	982.59
	Energy	Agri-Res.	7.99	8.2	8.41
		Fugitive	20.7	13.92	14.66
		Dung	29.24	30.01	30.8
		Charcoal	66.35	69.82	68.63
		Fuel Wood	219.86	226.86	232.31
	Lan.&For.	Agri-Res.	8.45	9.22	9.79
		Forest Burnning	60.23	59.33	58.44
	Waste	Ind.waste water (aa)	1.07	1.10	1.14
		Landfill	27.31	26.35	26.92
<b>Total</b>		<b>1586.38</b>	<b>1595.38</b>	<b>1593.02</b>	
NO <sub>x</sub>	Agricul.	Savannah	75.89	73.24	71.26
	Energy	Bagasse	0.42	0.43	0.44
		Charcoal	3.86	4.06	3.99
		Dung	5.13	5.27	5.4
		Agri-Res.	7.14	7.33	7.52
		Fuel Wood	54.63	56.33	57.73
	Lan.&For.	Agri-Res.	8.72	9.54	10.12
		Forest Burning	14.97	14.74	14.52
<b>Total</b>		<b>170.75</b>	<b>170.85</b>	<b>170.98</b>	
N <sub>2</sub> O	Agricul.	Savannah	2.12	2.04	1.97
	Energy	Charcoal	0.11	0.11	0.11
		Dung	0.14	0.15	0.15
		Agri-Res.	0.2	0.21	0.21

		Fuel Wood	1.51	1.56	1.6
	Lan.&For.	Agri-Res.	0.25	0.27	0.28
		Forest Burning	0.41	0.41	0.4
		<b>Total</b>	<b>4.74</b>	<b>4.75</b>	<b>4.72</b>

Note:- The inventory of GHGs was done by the EERC (formerly EEA). Table 1 was prepared by EERC. To meet uniformity of the calendar system, we have interpolated the values from Table 1 and produced Table 2 for the period 1990-1992. For example the interpolation for 1990 is done by averaging the values given for 1989/90 and 1990/91 provided in Table 1.