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ETHIOPIA NATIONAL GREENHOUSE GAS INVENTORY FOR THE WASTE SECTOR: 1990 - 2019

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Acronyms

AR2	**IPCC Second Assessment report**
BOD	Biochemical Oxygen Demand
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
COD	Chemical Oxygen Demand
CCSA	Central Statistics Agency
DOC	Degradable Organic Carbon
DOCf	Fraction of Degradable Organic Carbon
EMEP/EEA	European air pollutant emission inventory guidebook
FOD	First Order Decay
GDP	Gross Domestic Product
$GgCO_2eq$	Gigagrams Carbon Dioxide equivalent
GHG	Greenhouse Gas
GTPII	Second Growth and Transition Plan
GWP	Global Warming Potential
IPCC	Intergovernmental Panel on Climate Change
MCF	Methane Correction Factor
MoUDC	Ministry of Urban Development and Construction
MSW	Managed Solid Waste
MSWDs	Municipal Solid Waste Disposal Site
MW	Megawatts
N_2O	Nitrous oxide
NDC	Nationally Determined Contributions
NMVOC	Non-Methane Voltaic Organic Compounds
NOxs	Nitrogen oxides
OX	Oxidation Factor
QA/QC	Quality Assurance/Quality Control
SOx	Sulphur Oxides
STC	Sub-Technical Committee of CRGE initiative
SWDS	Solid Waste Disposal Sites
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WASH	Water, Sanitation and Hygiene

NATIONAL INVENTORY REPORT WASTE SECTOR

1 Overview of Waste Sector

1.1 Ethiopia Waste Sector Overview

Ethiopia's waste generation has been on the rise owing to the country's rising population and recent industrial growth. The increase in per capita Gross Domestic Product (GDP) drives waste generation due to the higher rates of solid and liquid waste generation. The per capita solid waste generation is projected to increase from 0.33 kg/person/day in 2010 to 0.44 kg/person/day in 2030 (Worku, 2011). Urbanisation and transition of small population centres into larger towns and cities is also driving emissions through the higher per capita solid waste generation. The number of urban centres with at least 20,000 people is projected to increase from 86 in 2010 to 237 in 2030 (Worku, 2011)

The development of solid waste and wastewater management facilities has not been commensurate with the rates of waste generation. As of 2020, only Addis Ababa had a managed dumpsite, although its capacity was not matching the city's solid waste generation rates (Worku, 2011). Open burning has been the most common waste disposal method in urban areas due to unavailability of waste collection and disposal services. Most industries discharge wastewater into water bodies without treatment (Worku, 2011). Ethiopia has made much progress in extending the provision of Water, Sanitation and Hygiene (WASH) services from the 1990 very low base of 19 per cent for water supply and 3 per cent for sanitation coverage, to 52 per cent and 63 per cent access to WASH in rural and urban areas respectively by 2010 (FDRE, 2016).

The country aims, in its Environmental policy, to provide human and domestic waste disposal facilities, give priority to waste collection services and to its safe disposal (FDRE, 1997). Further, the country intends to recycle liquid and solid wastes from homesteads and establishments for the production of energy, fertiliser and for other uses. Ethiopia targets to increase waste collection and disposal coverage to 90% in 75 urban centres, as well as increasing the power generating capacity of the country from 4,180 Megawatts (MW) in 2014/15 to 17,208MW by 2019/20; of which, 50MW coming from wastes (Second Growth and Transition Plan (GTPII)) (FDRE, 2016).

The Updated Nationally Determined Contributions (NDC) of Ethiopia targets a total emission reduction of 6.54 $MtCO_2$ eq from Ethiopia's waste sector (FDRE, 2021). Most Ethiopian municipality administrations are responsible for waste collection. However, this is a daunting task for the municipalities as up to 43 per cent of the waste is collected for disposal in unmanaged landfills, while the rest remains in the streets or is dumped in open spaces (Worku, 2011). The country is running a waste to energy project based in Addis Ababa's 36-hectare municipal landfill that has been operating for nearly 50 years, since 1968. The landfill that is currently 85 per cent full, was recently closed and transformed into the Repi project.

1.2 Overview of GHG emissions in 2020.

The Waste sector Greenhouse gases (GHG) inventory covers carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), as well the precursors gases carbon monoxide (CO), nitrogen oxides (NOxs), sulphur dioxide (SO_2) and non-methane volatile organic compounds (NMVOCs) (Table 1-1).

Table 1-1: GHG emissions totals by Gas-2017.

Categories	Emissions [Gg]						
	CO_2	CH_4	N_2O	NOx	CO	NMVOCs	SO_2
4 - Waste	130.16	183.59	5.98	NE	NE	10.92	NA
4.A - Solid Waste Disposal	NA	13.29	0.00	NE	NE	NE	NA
4.A.1 - Managed Waste Disposal Sites							
4.A.2 - Unmanaged Waste Disposal Sites							
4.A.3 - Uncategorised Waste Disposal Sites							
4.B - Biological Treatment of Solid Waste		NE	NE	NE	NE	NE	NE
4.C - Incineration and Open Burning of Waste	130.16	54.53	0.72				
4.C.1 - Waste Incineration	NE	NE	NE	NE	NE	NE	NE
4.C.2 - Open Burning of Waste	130.16	54.53	0.72	28.10	493.38	10.87	0.97
4.D - Wastewater Treatment and Discharge	NA	115.77	5.26			0.05	
4.D.1 - Domestic Wastewater Treatment and Discharge		111.75	5.26	NE	NE	NE	NA
4.D.2 - Industrial Wastewater Treatment and Discharge		4.02		NE	NE	0.05	NA
4.E - Other (please specify)				NO	NO	NO	NO

In 2017, a total of 5,838.98 $GgCO_2eq$ GHG emissions were emitted from the waste sector in Ethiopia. The highest emissions were from domestic wastewater contributing 68.13%, followed by open burning of waste (25.65%), solid waste disposal with 4.78% and the least from industrial wastewater accounting for 1% (Table 1-2 and **Error! Reference source not found.**).

Table 1-2: GHG emissions from the waste sector in Gg CO_2eq

Categories	Emissions [Gg CO_2eq]				
	CO_2	CH_4	N_2O	Total	% Contribution
4 - Waste	130.16	3855.28	1853.54	5838.98	100.00%
4.A - Solid Waste Disposal	NE	279.09	NE	279.09	4.78%
4.A.1 - Managed Waste Disposal Sites	0	0	0	0	
4.A.2 - Unmanaged Waste Disposal Sites	0	0	0	0	
4.A.3 - Uncategorised Waste Disposal Sites	0	0	0	0	
4.B - Biological Treatment of Solid Waste	NE	NE	NE	NE	0.00%
4.C - Incineration and Open Burning of Waste	130.16	1145.04	222.34	1497.54	25.65%
4.C.1 - Waste Incineration	NE	NE	NE	NE	0.00%
4.C.2 - Open Burning of Waste	130.16	1145.04	222.34	1497.54	25.65%
4.D - Wastewater Treatment and Discharge	0	2431.15	1631.204	4062.35	69.57%
4.D.1 - Domestic Wastewater Treatment and Discharge	0	2346.81	1631.204	3978.02	68.13%
4.D.2 - Industrial Wastewater Treatment and Discharge		84.34	0	84.34	1.44%
4.E - Other (please specify)		0	0	0	0.00%

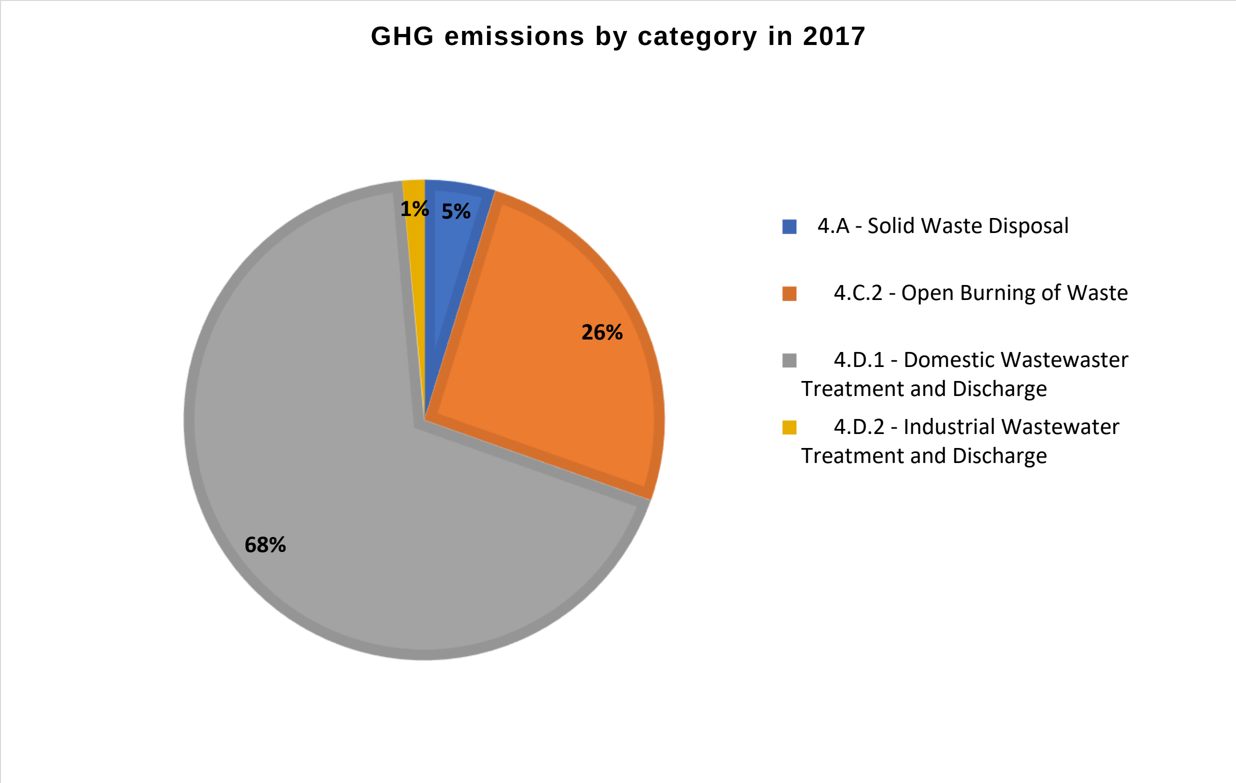

Figure 1-1: GHG emissions from Waste Sector by source category

Most of the emissions from Ethiopia's Waste sector were CH_4 comprising 57%, followed 41% CO_2 and 2% N_2O (Figure 1-2).

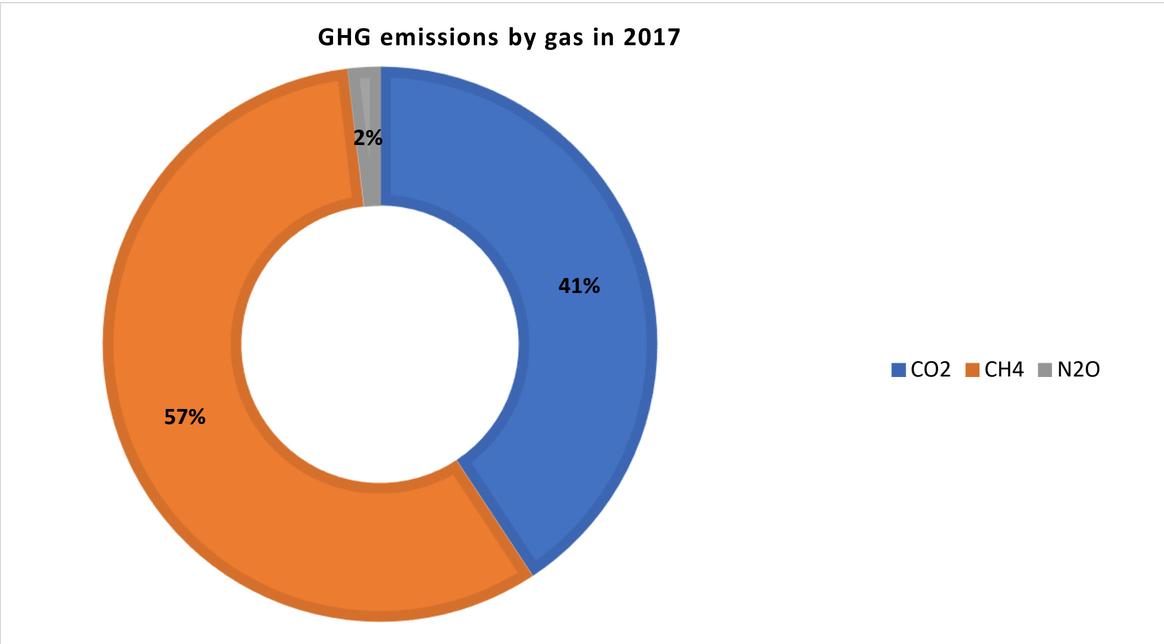

Figure 1-2: GHG emission by gas in 2017

Trends in CO_2 are presented in Figure 1-3. CO_2 emissions more than doubled from 63.71Gg in 1990 to 137.12Gg in 2020. The emissions showed a steady and gradual increase over the whole time series owing to rising trends in solid waste and wastewater generation.

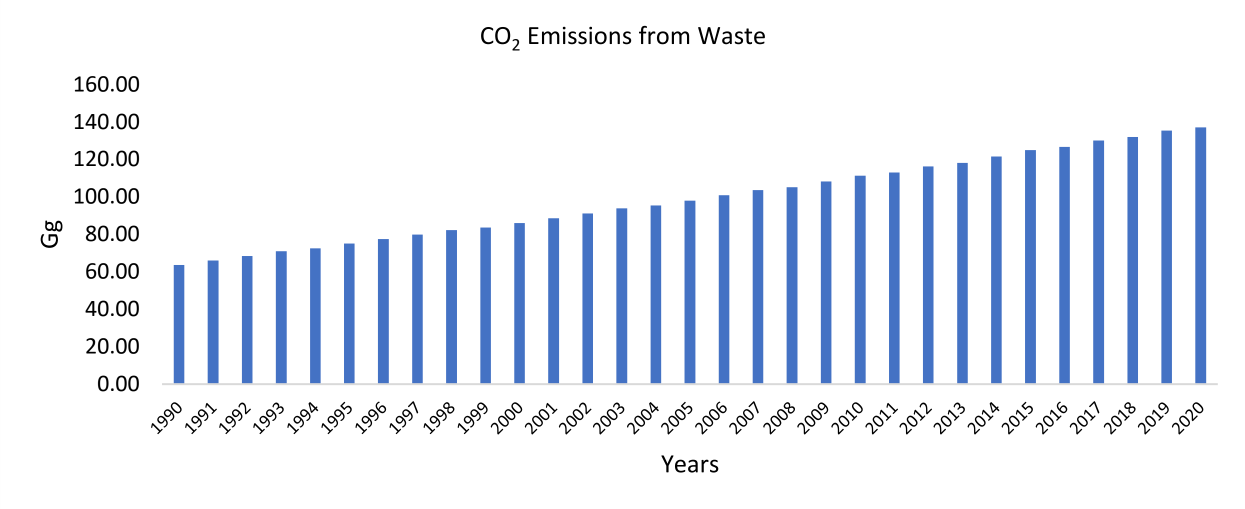

Figure 1-3: CO_2 emissions from Ethiopia waste sector.

CH_4 emissions rose by 149% from 80.50 Gg in 1990 to 189.31Gg in 2019 (Figure 1-4). There was a steady emission rise from 1990 to 2019, followed by a sharp decline of emissions in 2020. This huge difference can be attributed to the fact that emissions from Domestic waste water treatment emissions were not reported for the year 2020 (Figure 1-6). Domestic wastewater contributed for nearly two thirds of the emissions from the Ethiopia's waste sector over the whole time series from 1990 to 2019. It was also the major contributor of CH_4 emissions.

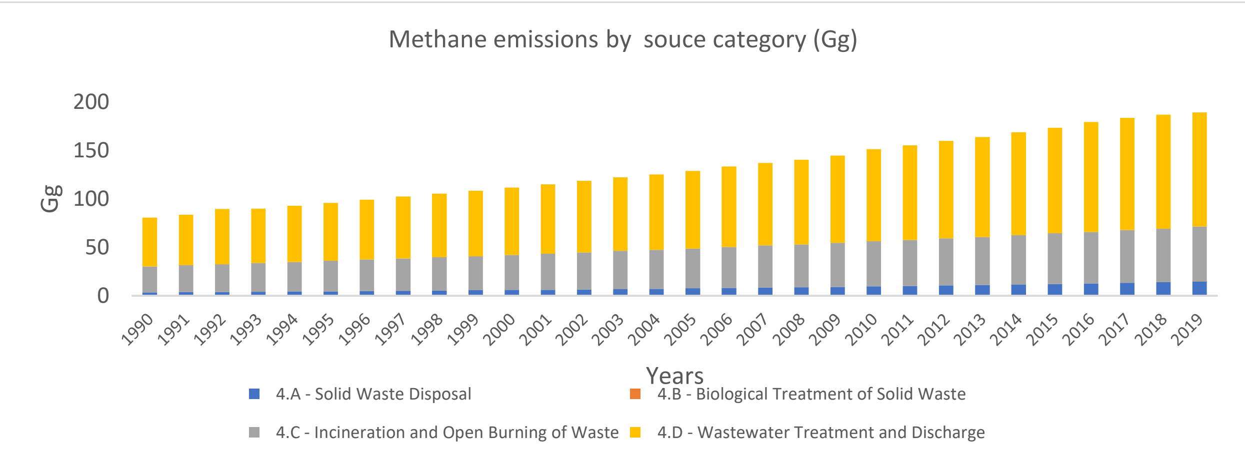

Figure 1-4: CH_4 emissions from Waste sector

The least emission by mass were N_2O, rising from 2.72Gg in 1990 to 6.29Gg in 2019, then to 0.67 Gg in 2020. The increase followed the rising trends in solid waste and wastewater generation over the years. The sharp drop in 2020 is a result of the absence of Domestic wastewater emissions in 2020.

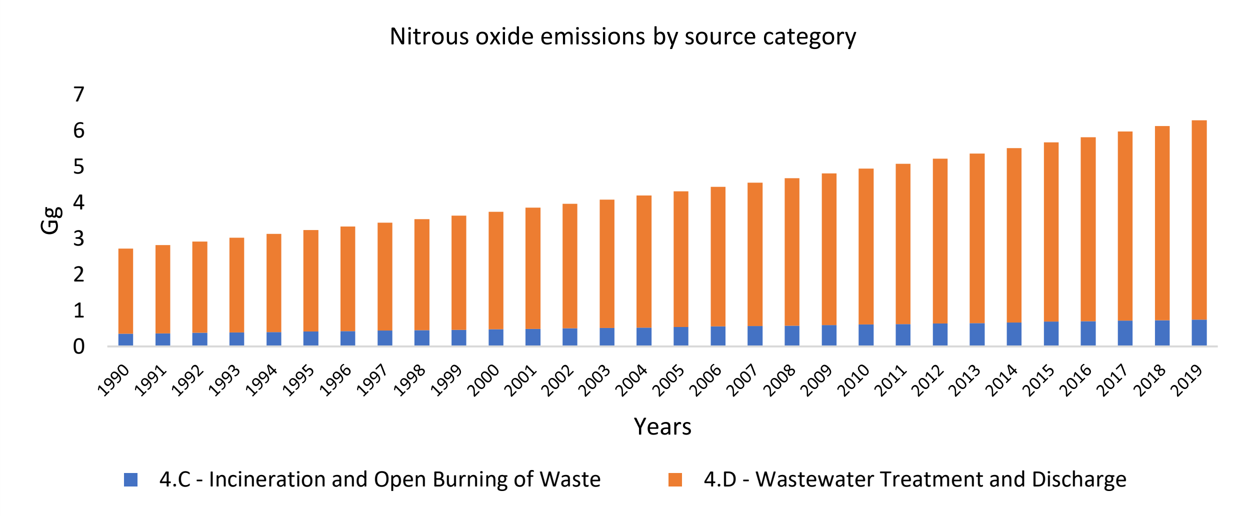

Figure 1-5: N_2O emissions from waste sector

1.3 Changes in emissions in the reporting years

There were significant differences between 1994 (INC) and 2013 (SNC) for all categories in the waste sector, ranging from 346% to 504%. The highest difference was obtained from 4.A – Solid waste disposal. Comparisons between total waste emissions reported in the INC and TNC give a small difference of 24%, with solid waste disposal giving a negative percentage of about -52%, whilst only wastewater use recorded a huge percentage difference of 385 %. The SNC reported the highest emissions from the waste sector which justifies the negative percentage differences obtained when the TNC emissions were compared with the SNC emissions. However, this does not apply to Open burning which obtained a percentage difference of 1,344.57. Wastewater use emissions in the SNC and TNC were almost equal, with a difference of 8.77%. Opening burning was not reported in the INC (Table 1-3).

Table 1-3: Differences in emissions between reporting years

Categories	**INC 1994**	**SNC 2013**	**TNC 2017**	**%INC/SNC**	**%INC/TNC**	**%SNC/TNC**
Waste Total	1428.9	7420.609	1776.63	419.3232	24.33548	-76.0582
4.A - Solid Waste Disposal	592.2	3582.069	279.0924	504.8749	-52.8719	-92.2086
4.C.2 - Open Burning of Waste		103.6665	1497.537			1344.572
4.D Wastewater Use	836.7	3734.873	4062.354	346.3814	385.521	8.768204

1.4 Overview of methodology and completeness.

The 2006 Intergovernmental Panel on Climate Change (IPCC) guidelines for GHG inventory compilation were used in the estimation of GHGs from the Waste Sector. Default Methodology (Tier 1) was used for all the source categories. Table 1-4 summarises the methodologies, activity data sources and the categories reported in this inventory.

Table 1-4: Summary of methodologies

Categories	Gg						
	CO_2	CH_4	N_2O	NOx	CO	NMVOCs	SO_2
4 - Waste							
4.A - Solid Waste Disposal		T1,	T1	EMEP/ EEA[1]	EMEP/ EEA	EMEP/ EEA	NA
4.A.1 - Managed Waste Disposal Sites							
4.A.2 - Unmanaged Waste Disposal Sites							
4.A.3 - Uncategorised Waste Disposal Sites							
4.B - Biological Treatment of Solid Waste	NE	NE	NE	NE	NE	NE	NA
4.C - Incineration and Open Burning of Waste							
4.C.1 - Waste Incineration	NE	NE	NE	NE	NE	NE	NA
4.C.2 - Open Burning of Waste	T1	T1	T1	T1	T1	T1	NA
4.D - Wastewater Treatment and Discharge							
4.D.1 - Domestic Wastewater Treatment and Discharge		T1	T1	NE	NE	NE	NA
4.D.2 - Industrial Wastewater Treatment and Discharge		T1		EMEP/ EEA	EMEP/ EEA	EMEP/ EEA	NA EEA
4.E - Other (please specify)				NO	NO	NO	NO

1.5 GWP Global Warming Potentials (GWP)

The Global Warming Potentials (GWPs) from the IPCC Second Assessment Report (AR2) were applied in converting GHG from units of mass to CO_2eq, and are shown in Table *1-5*.

Table 1-5: Global warming Potentials from the IPCC AR2

Name of gas	**Chemical formula**	**GWP**
Carbon dioxide	CO_2	1
Methane	CH_4	21
Nitrous oxide	N_2O	310

Source: IPCC AR2, 1995

1.6 Trends in GHG emissions

GHG emissions from the waste sector have been steadily rising from 2,597.18 Gg CO_2eq in 1990. The 2019 emissions of 6,054.35 GgCO_2eq are more than double the 1990 emissions as shown Figure 1-6. Domestic wastewater treatment and open burning of waste have been the major sources of emissions from waste throughout the time series. The growth in GHG emissions is related to the rising population and growth in economic activities.

[1] EMEP/EEA 2019 Guidebook

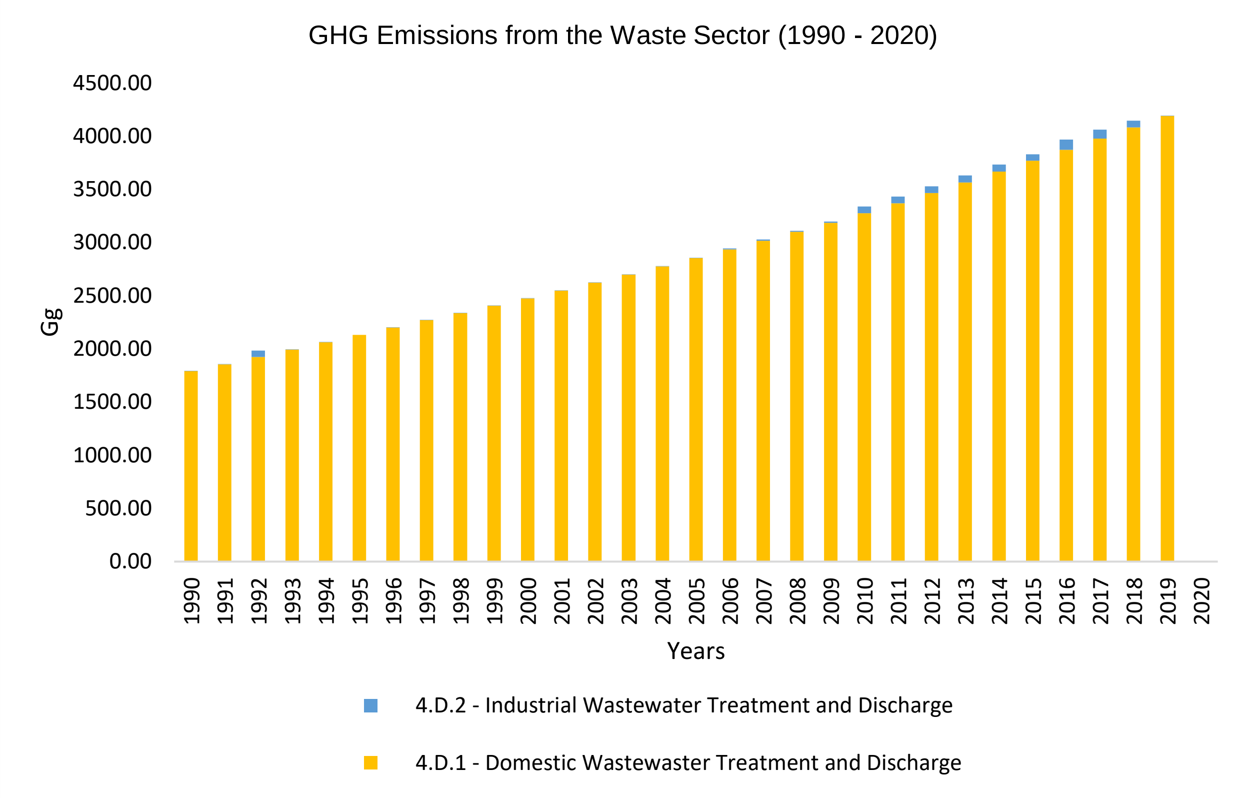

Figure 1-6 : Waste sector emissions by subcategory 1990-2020

1.7 Emissions by source category

1.7.1 Solid Waste Disposal-4 A

The GHG emissions from solid waste in Ethiopia includes methane emissions from municipal solid waste disposal sites (SWDS) defined as unmanaged shallow and uncategorized, in accordance with the classification of 2006 IPCC Guidelines (IPCC, 2007). These are emitted from the country`s major cities. Solid waste emissions were estimated for urban areas only since waste dumping is prevalent in these areas. Methane generation from these dump sites is very little owing to the low collection rates. There is neither waste separation at the SWDS) nor segregation at sources producing the waste. Engineered landfills are not yet developed in Ethiopia.

In the capital Addis Ababa 70% of the generated solid waste is collected and disposed in the dumpsite, whereas 5% is recycled, 5% is composted and the remaining, approximately 20% of the solid waste is uncollected and dumped in unauthorized areas such as open fields, ditches, sewers, street-sides and all other available open-spaces in the city (Worku, 2011). Open dumping in rural and most growth points generates insignificant amount of CH_4 emissions as aerobic digestion of waste is predominant, hence was not considered in the inventory.

In 2017 the total waste generated was estimated at 2,449.012Gg based on an urban population of 21.61 million and waste generation rate of 113.15kg/cap/y (MoUDC). The amount of waste sent to SWDS was estimated at 2,445.17 Gg based on an average collection rate of 40% of the total generated waste.

There were no methane emissions in 1990 due to the default assumption from the FOD method (2006 IPCC Guidelines) where methane production is assumed to start on the 1st of

January in the year after deposition and have a residence time of 6 months. Methane emissions from SWDS at landfills showed an increase from 73.63 GgCO_2eq in 1990 to 320.71 Gg CO_2eq 2020. The resulting annual CH_4 emissions and trend is presented in Figure 1-7.

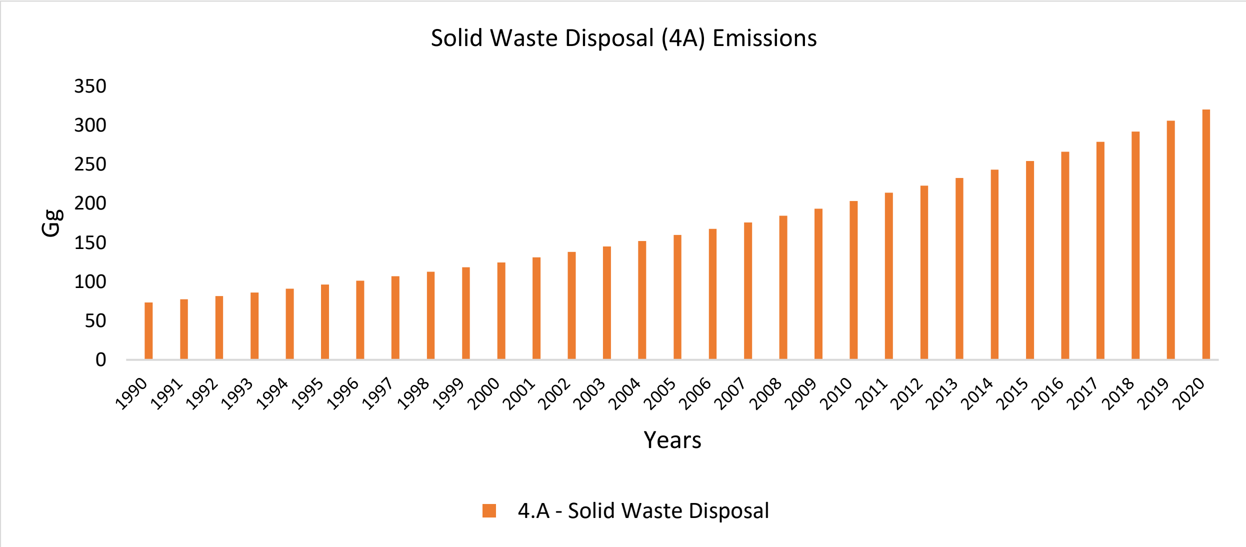

Figure 1-7: MSW Methane emissions trend 1990-2019

a. Methodological issues

Estimation of CH_4 emissions from solid waste was based on the 2006 IPCC Guidelines using a Tier 1 First Order Decay (FOD) method. The National Waste Management Strategy for Ethiopia and IPCC default values were used to determine parameters used in the FOD model. The FOD method assumes that the degradable organic component (degradable organic carbon, DOC) in waste decays slowly throughout a few decades, during which CH_4 and CO_2 are emitted. Ethiopia does not have a country specific methodology for estimating emissions from solid waste handling and therefore default parameters in the 2006 IPCC Guidelines were used where country specific data was not available. The FOD equations 3.2 to 3.6 (2006 IPCC Guideline, Vol 5, Chapter3) were used to estimate the methane emissions from solid waste.

b. Activity data

The transition to use FOD method which requires 50 or more years, led to the need to restore the series of data on Managed Solid Waste (MSW) in Ethiopia from 1960. Statistical data on urban population and default country specific generation rate (113.15kg/cap/yr.) was used for the period 1960 -2019 on urban population in order to form a coherent set of data on historical MSW sent to dump sites. The country waste generation rate of 113.15kg/cap/y (Worku, 2011) was used.

Table 1-6: Estimated total solid waste generated (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Solid Waste	992.72	1048.46	1107.82	1170.38	1235.08	1295.61	1354.61	1414.28	1475.25	1538.01	1603.33	1671.11	1741.72	1814.85	1890.53	1968.76

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Solid Waste	2049.68	2135.49	2248.50	2367.34	2493.05	2625.75	2765.85	2910.17	3060.95	3217.71	3380.57	3549.41	3724.90	3907.30

c. Emission Factors

Methane Correction Factor (MCF)

Estimation of MCF values was based on the weighted average taking into account the distribution of MSW flows into uncategorized and shallow unmanaged landfills. The default MCF of 0.4 and 06 for unmanaged shallow (<5m waste) and uncategorized respectively were used (IPCC, 2007). The weighted MCF is 0.58.

Waste Composition and DOC

Waste composition in the draft Solid Waste Management Strategy was used and is shown in *Table 1-7*.

Degradable Organic Carbon (DOC)

DOC is the portion of organic carbon present in solid waste that is susceptible to biochemical decomposition. Default values for DOC in different waste types is given below in Table 1-7 provided in Volume 5, Chapter 2, Table 2.4.

Table 1-7: Default values for DOC in different waste types

Waste Type	DOC values (%)
Paper and Cardboard	6.63
Textiles	3.07
Food waste	51.01
Nappies	0.7
Garden and Park Waste	4.45
Wood	7

Source:(MUDC)

Fraction of Degradable Organic Carbon which Decomposes (DOCf)

Fraction of DOC_f default value of 0.5 in the 2006 IPCC Guidelines was used (Vol.5, Chapter 3, Page 3.13).

Constant k and half-life t1/2

The half-life value is the time taken for the DOC_m in waste to decay to half its initial mass. The constant k is related to $t_{1/2}$ by the equation:

$k = \ln(2)/t_{1/2}$

Equation 1-1: Relationship between half-life and reaction rate constant

Source: (IPCC, 2007)

For Ethiopia in the tropical dry zone default k and $t_{1/2}$ are shown Table 1-8 as provided by the 2006 IPCC guidelines Vol 5 Chapter 3, Tables 3.3 and 3.4.

Table 1-8: Constant k and half-life $t_{1/2}$

Waste Type	Constant (k)	Half-life $t_{1/2}$
Paper and Cardboard	0.04	17
Food	0.06	12
Garden and Park Waste	0.05	14
Wood	0.02	35

Source: (IPCC, 2007)

Methane recovered R

There is mostly no methane recovery either for flaring or for energy use at the landfills in Ethiopia. The default value of R = zero is used (2006 IPCC Guidelines (Vol. 5, Chapter 3) was, therefore, used

Oxidation Factor (OX)

The open dumps in Ethiopia are not covered with aerated material hence the default value for OX of zero; according to the 2006 IPCC Guidelines (Volume 5, Chapter 3, Table 3.2) was used.

d. Category-specific QA/QC and Verification

Comparison of selected activity data and regional values was conducted. Analysis of activity data trends along with emission trends along the time series was also performed.

1.7.2 Biological treatment of solid waste-4B

Composting is considered one of the most reliable solid waste treatment options for cities in Ethiopia (FDRE, 2015). The establishment of the solid waste composting project the NAMA Compost that compiled by UNDP under MOUI. Methane and nitrous oxide are the key emission sources from biological treatment of solid waste through composting.

There was a 48% increase in both CH_4 and N_2O from 2019 to 2020 as shown in Figure 1-8.

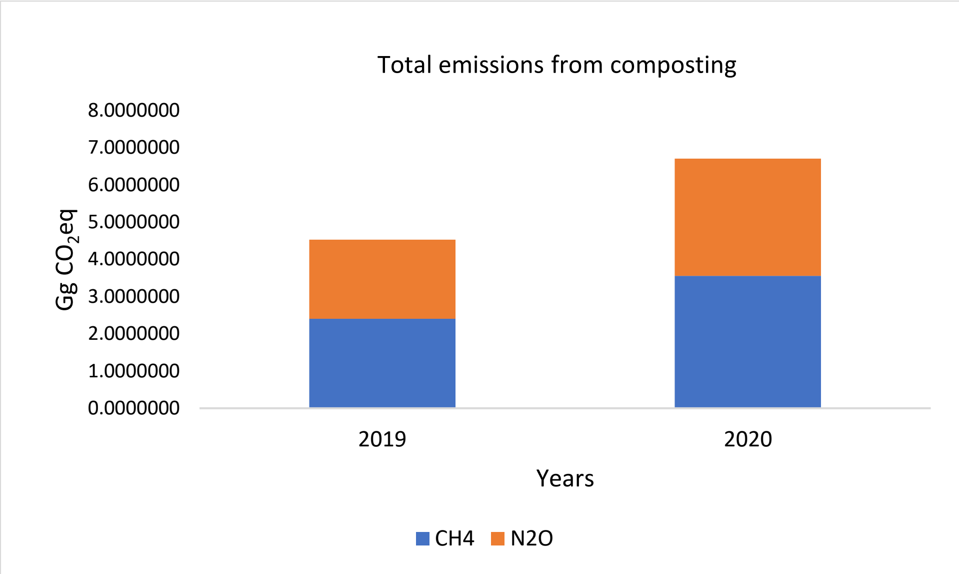

Figure 1-8: GHG emissions from composting

a. Methodological issues

The calculation of CH_4 and N_2O emissions from composting was conducted in accordance with the 2006 IPPC default methodology following Equations 4.1 and 4.2, respectively, in Volume 5 of the 2006 IPCC Guidelines, chapter 4.

b. Activity data

The quantities of composted from the cities were obtained from the MUDC (Table 1-9).

Table 1-9: Waste composting data

Year	Amount of compost produced in Six NAMA compost cities in tones	In Addis Ababa	Total
2019	28,572		28,572
2020	41,492	803	42,295
2021(6 month report)	26,537		26,537

Source: MUDC, 2021

c. Emission Factors

The default emission factors on wet basis for CH_4 and N_2O were 4g/kg and 0.3g/kg, respectively, taken from Table 4.1 in the 2006 IPCC Guidelines, Chapter 4 Volume 5.

d. Category-specific QA/QC

General QA/QC as outlined in section 1.6.1 on solid waste treatment were applied.

1.7.3 Incineration and Open Burning of Waste-4 C

The section covers GHG emissions from open burning of waste. GHG emissions from incineration were not estimated since the data were not available.

1.7.3.1 Waste Incineration-4 C 1

GHG emissions from waste incineration were not estimated. Healthcare waste has been rising given the rising number of private clinics. However, there are currently no adequate facilities for treatment and disposal of healthcare waste (Worku, 2011). The activity data was also not available.

1.7.3.2 Open Burning of Waste-4 C 2

Open burning of waste is frequent in Ethiopia with fires being recorded at dump sites, especially in urban areas. Almost all small urban centres and rural villages do not have waste management systems. Waste is not collected and individual households and commercial establishment dump waste in any open spaces. The urban and rural population (Annex D) was used for estimating waste that is openly burned. Open burning of waste releases CH_4, CO_2, N_2O, NOx, CO, NMVOC and SO_2 emissions. Total emissions from open burning of waste increased from 732.98Gg CO_2eq in 1990 to over 1,577.62 Gg CO_2eq in 2020 (Figure 1-9). The increase in the GHG is directly related to population growth.

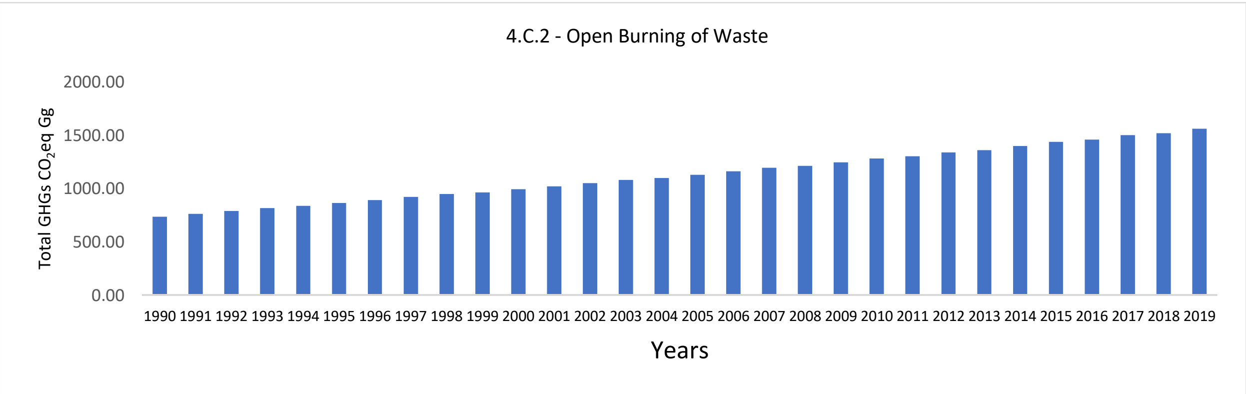

Figure 1-9: Total GHG emissions from open burning of waste, 1990-2020

1.7.3.3 Precursors

Carbon monoxide (CO) was the main gas emitted, followed by oxides of nitrogen (NOx) over the whole time series, as presented in Figure 1-10.

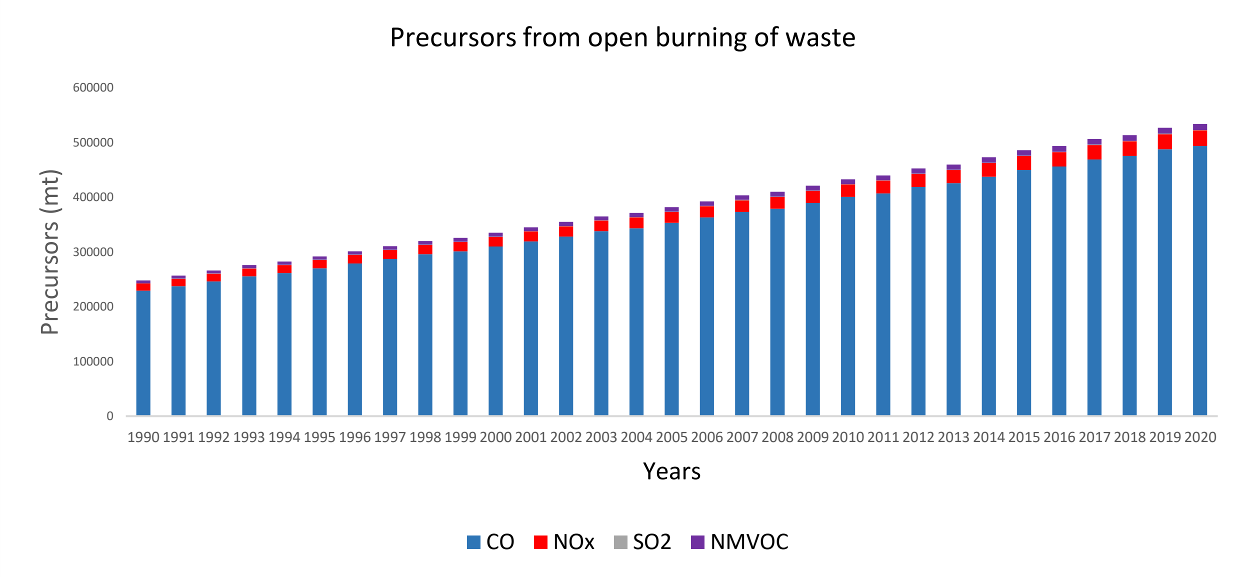

Figure 1-10: Precursors from open burning of waste

1.7.4 Wastewater Treatment and Discharge-4 D

Quantitative data on liquid waste management at city level were not available. Liquid waste in Ethiopia, includes:

- Domestic and Commercial wastewater/sewage consisting of grey water and black water,
- Industrial wastewater,
- Agricultural waste water,
- Urban storm water runoff,
- Leachate from landfills/solid waste dumps
- Sludge (septic tanks, industries, and sewerage treatment plants).

Methane and nitrous oxide emissions from the treatment and discharge of liquid wastes and sludge from housing and commercial sources through wastewater sewage collection and treatment systems, pit latrines and discharge into surface waters are covered in this section. Total GHG emissions from wastewater treatment increased from 1,790Gg CO_2eq in 1990 to over 4,190 Gg CO_2eq in 2019 (Figure 1-11). Throughout the time series, domestic wastewater treatment accounted for most emissions.

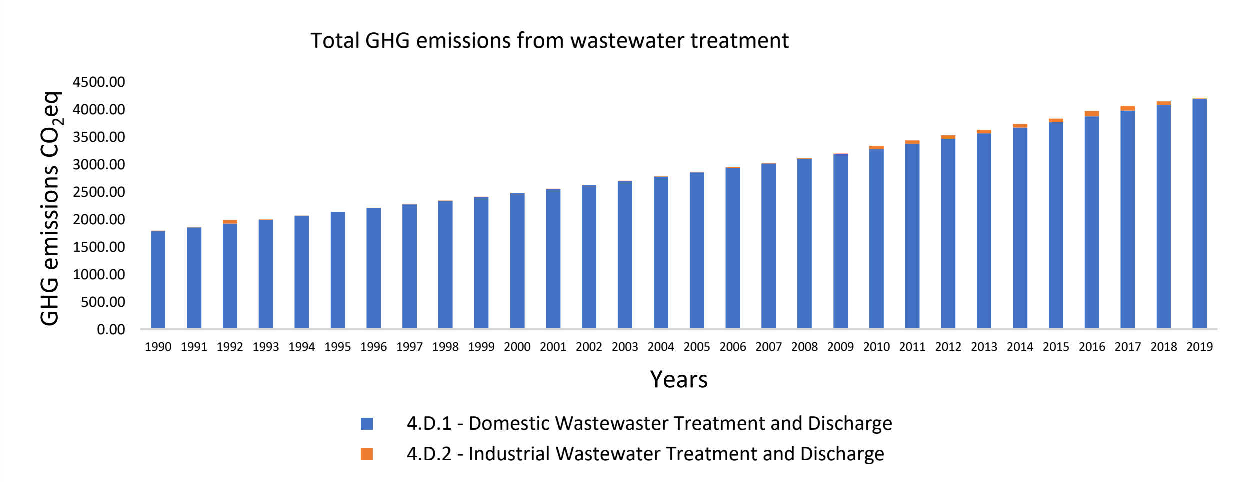

Figure 1-11: Total GHG emission from wastewater treatment

1.7.4.1 Domestic Wastewater Treatment and Discharge-4 D 1

GHG emissions from domestic wastewater have been steadily rising from 1990 to 2019 in line with population growth Figure *1-12*.

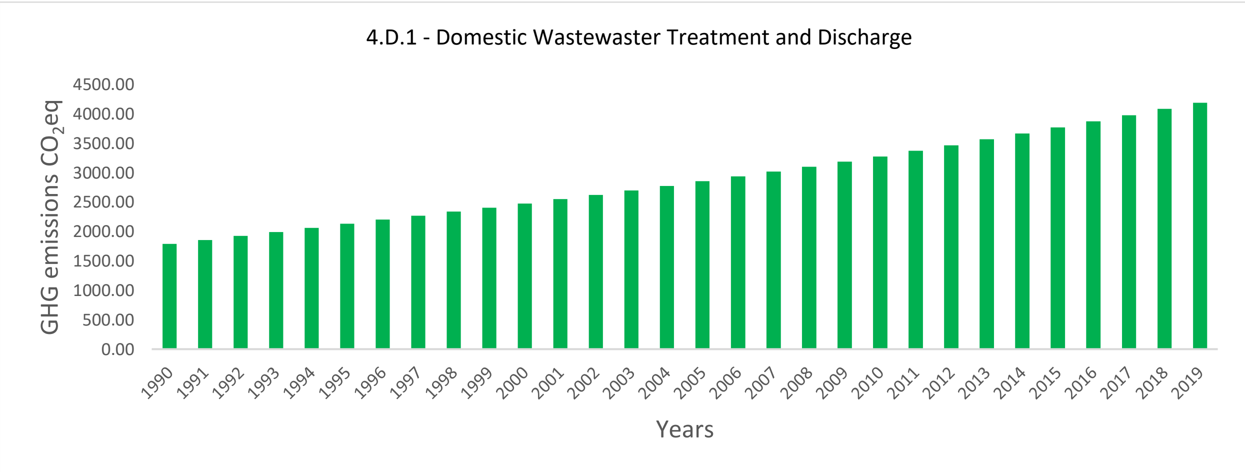

Figure 1-12: Emissions from Domestic wastewater treatment and discharge

a. Methodological issues

Tier 1 methodology was applied, following Decision Tree for CH_4 emissions from domestic wastewater (Figure 6.2, in Chapter 6, Volume 5 of the 2006 IPCCC Guidelines). The Tier 1 method applies default values for the emission factor and activity parameters. This method is considered good practice for countries with limited data, as was the case for Ethiopia in the TNC.

b. Emission Factors and parameters

Default Emission factors were obtained from the IPCC Guidelines (IPCC, 2007) and are shown in Table 1-10.

Table 1-10: Wastewater parameters

Parameter (units)	Value
Emission Factor (kg N_2O-N/kg N)	0.005
Fraction of industrial and commercial co-discharged protein (Find-com) (-)	1.25
Fraction of nitrogen in protein (Fnpr) (kg N/kg Protein)	0.16
Degradable organic component - BOD [kg BOD/cap/yr] (rural and urban)	13.505
Maximum methane producing capacity - B0 [kg CH_4/kg BOD] (Centralized, aerobic treatment plant, Latrine, Septic system)	0.6
Nitrogen removed with sludge (N sludge) (kg)	0
Fraction of non-consumption protein (Fnon-con) (-)	1.1
Fraction of Population Income Group - Ui [Fraction] Rural Urban high income Urban low income	0.62 0.08 0.3
Per capita protein consumption (Protein) (kg/person/Year)	28.61
Emissions from Wastewater plants (Default value is zero (0)) (kg N_2O/yr)	0
Degree of utilization - Tij [Fraction]	

Income Group	**Type of treatment or discharge pathway**	**Value**
Rural	Centralized, aerobic treatment plant	0.1
Rural	Latrine	0.28
Rural	Septic system	0.02
Urban high income	Centralized, aerobic treatment plant	0.37
Urban high income	Latrine	0.31
Urban high income	Septic system	0.32
Urban low income	Centralized, aerobic treatment plant	0.34
Urban low income	Latrine	0.24
Urban low income	Septic system	0.17

c. Time series consistency

The amount of wastewater used for the whole time series was determined from the population figures obtained from CSA.

d. Category-specific QA/QC and Verification

Calculations were performed in spreadsheets to check if the activity data and parameters were correctly entered into the IPCC Inventory Software.

e. Category-specific Recalculations

Recalculations were conducted back to 1990. The comparisons for the reporting years are shown in Table *1-17*: .

f. Planned Improvements

1.7.4.2 4 D 2 Industrial Wastewater Treatment and Discharge

Methane emissions from mainly the discharge of untreated industry wastewater are covered in this section. The industries covered include alcohol refining; beer and malt; dairy products; fish processing; meat and poultry; sugar refining; vegetable oils, as well as vegetables, fruits and juices. About 90% of the industries in Addis Ababa are discharging their waste waters into nearby water bodies (Worku, 2011). The situation is the same in other cities.

Emissions were consistently low in the years 1990 and 1991, with spike in 1992, then maintaining the low levels up to 2005 Figure 1-12). There was a slight increase in emissions in 2006, which remained constant up to 2009. Another sharp increase was reported from 2010 and gradually fluctuating up to 2015. This was followed by a sharp increase in 2016, gradually declining in 2017 and 2018. The emissions significantly dropped in 2019.

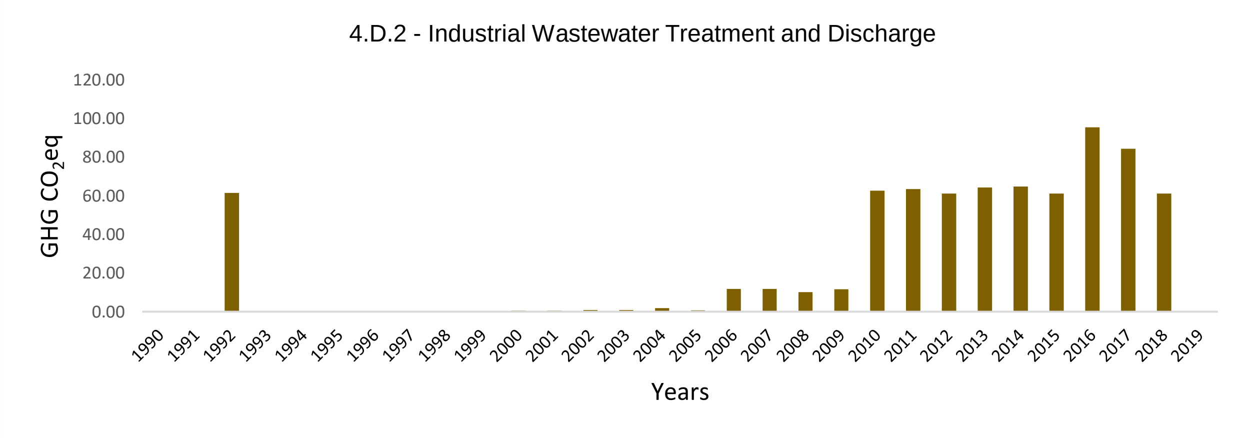

Figure 1-13: Industrial wastewater treatment and discharge

a. Methodological issues

Tier 1 methodology was applied, following the Decision Tree for CH_4 emissions from domestic wastewater (Figure 6.2, in Chapter 6, Volume 5 of the 2006 IPCCC Guidelines). The Tier 1 method applies default values for the emission factor and activity parameters was considered appropriate since data were scarce.

b. Activity data

Activity from production of alcohol refining; beer and malt; dairy products; fish processing; meat and poultry; sugar refining; vegetable oils, as well as vegetables, fruits and juices was used to calculate CH_4 emissions from industrial wastewater (Table 1-11).

Table 1-11: Industrial wastewater activity

Product	Units	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Coffee	tonne	0	0	0	0	0	16	31	34	28	0	300	115	259
Beer & malt	tonne	22251.03	24806	8627.398	33241.22	42979.6	41666.1	38830.46	41884.51	50993.8	0	79950.36	89645.1	59291.8
Meat	tonne	158	292	161	308	683	302	96	615	526	0	1194	849	224
Milk	tonne	1222.276	853.9086	110.9587	1510.585	1597.247	1485.406	1499.002	1329.138	1352.234	0	3156.496	3795.232	4299.172

	unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Coffee	tonne	563	16317	1544	2767	1984	1708	1407	19059	13807	591	5278	118	6581
Beer and malt	tonne	67602.41	70083	72451.45	92294.72	95712.71	130524.9	169319	181516.6	258503.2	300674.5	183085.6	393571.9	2366185
Meat	tonne	208	212	271	271	356	4449	20910	22702	22105	20596	19388	12418	11179
Milk	tonne	4770.199	5724.613	4753.955	5166.218	5683.083	8566.067	7781.587	8616.602	3952.594	9237.363	10949.03	16039.43	13041.14

Source; CSA

c. Emission Factors and parameters

Default parameters were obtained from the IPCC Guidelines

Table 1-12: Emission Factors and parameters

Type of treatment and discharge pathway or system	MCF 1
Untreated	
Sea, river and lake discharge	0.1
Recovered CH_4 in each industry sector (Ri) (kg CH4/yr)	0
Sludge removed in each industry sector (Si) (kg COD/yr)	0

Source: (IPCC, 2007).

d. Time series consistency

Production data were missing for most years and the GHG emissions trends were showed variations related mostly to data inconsistency.

1.7.5 Precursors from wastewater handling

The quantities of precursors from wastewater handling varied owing to data gaps (Figure 1-14).

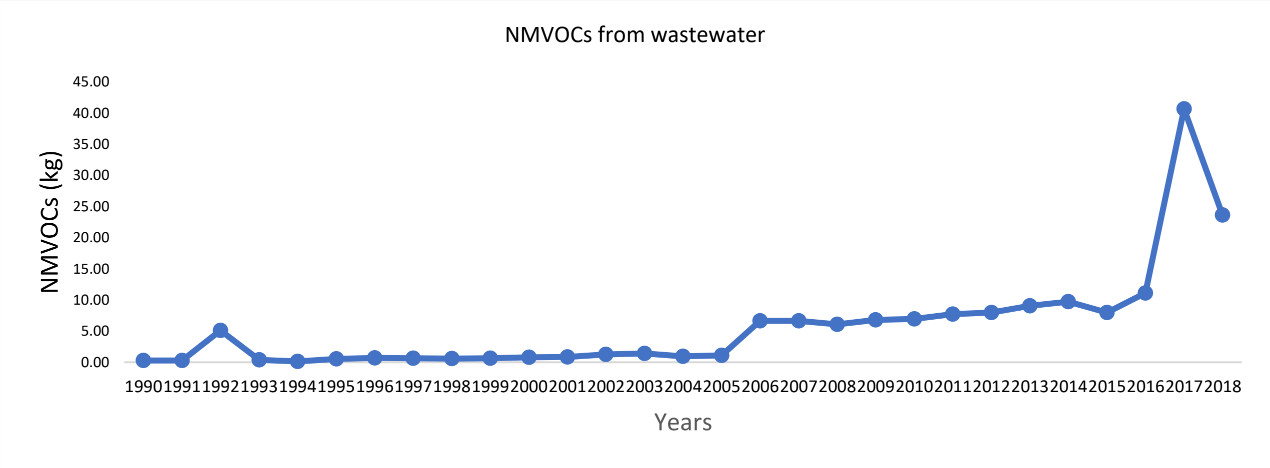

Figure 1-14: Precursors from wastewater handling

1.7.6 Other (please specify) -4 E

This category was not covered since it does not exist in Ethiopia

1.7.7 Long-term carbon storage

Some carbon will be stored over long time periods in SWDS. Wood and paper decay very slowly and accumulate in the SWDS (long-term storage). Carbon fractions in other waste types decay over varying time periods

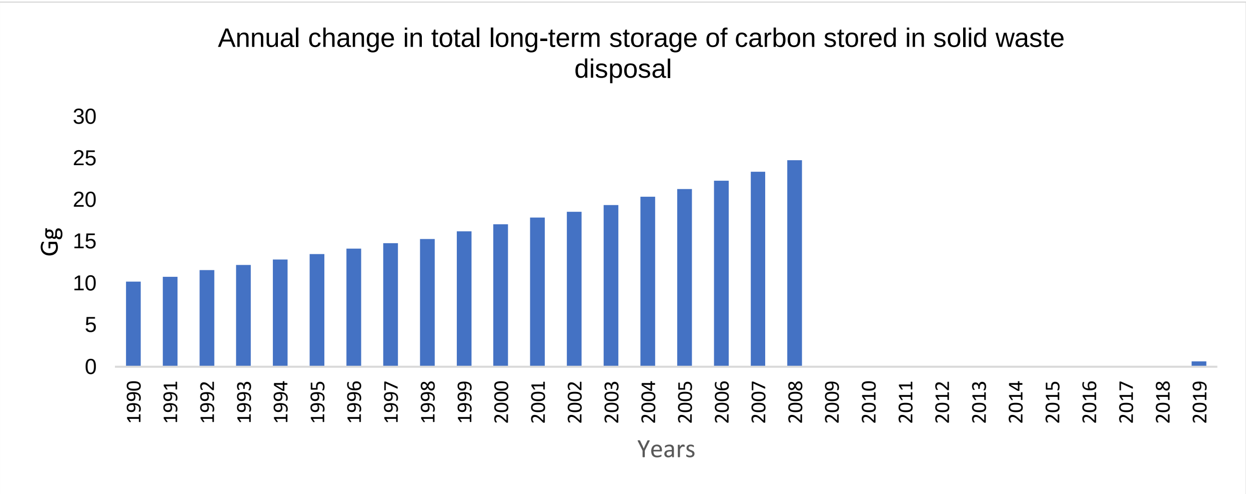

Figure 1-15: Stored carbon

a. Methodological issues

Estimation of CH_4 emissions from long-term carbon storage of carbon stored in solid waste was based on the 2006 IPCC Guidelines using a Tier 1 FOD method. The National Waste Management Strategy for Ethiopia and IPCC default values were used to determine parameters used in the FOD model. The FOD method assumes that the degradable organic component (degradable organic carbon, DOC) in waste decays slowly throughout a few decades, during which CH_4 and CO_2 are emitted. Ethiopia does not have a country specific methodology for estimating emissions from solid waste handling and therefore default parameters in the 2006 IPCC Guidelines were used where country specific data was not available. The FOD equations 3.2 to 3.6 (2006 IPCC Guidelines, Vol 5, Chapter3) were used to estimate the methane emissions from solid waste.

b. Activity data

The transition to use FOD method which requires 50 or more years, led to the need to restore the series of data on Managed Solid Waste (MSW) in Ethiopia from 1960. Statistical data on urban population and default country specific generation rate (113.15 kg/cap/yr.) was used for the period 1960 -2019 on urban population in order to form a coherent set of data on historical MSW sent to dump sites (Table *1-13*). The country waste generation rate of 113.15kg/cap/y (MUDC) was used.

Table 1-13: Estimated total solid waste generated (Gg)

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	2005
Solid Waste	992.72	1048.46	1107.82	1170.38	1235.08	1295.61	1354.61	1414.28	1475.25	1538.01	1603.33	1671.11	1741.72	1814.85	1890.53	1968.76

	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Solid Waste	2049.68	2135.49	2248.50	2367.34	2493.05	2625.75	2765.85	2910.17	3060.95	3217.71	3380.57	3549.41	3724.90	3907.30

c. Emission Factors

Methane Correction Factor (MCF)

Estimation of MCF values was based on the weighted average taking into account the distribution of MSW flows into uncategorized and shallow unmanaged landfills. The default MCF of 0.4 and 06 for unmanaged shallow (<5m waste) and uncategorized respectively were used (IPCC, 2007). The weighted MCF is 0.58.

Waste Composition and DOC

Waste composition in the draft Solid Waste Management Strategy was used and is shown in Table 1-14.

Degradable Organic Carbon (DOC)

DOC is the portion of organic carbon present in solid waste that is susceptible to biochemical decomposition. Default values for DOC in different waste types is given below in Table 1-14 provided in Volume 5, Chapter 2, Table 2.4 of the IPCC Guidelines.

Table 1-14: Default values for DOC in different waste types

Waste Type	DOC values
Paper and Cardboard	0.4
Textiles	0.24
Food waste	0.15
Nappies	0.24
Garden and Park Waste	0.20
Wood	0.43

Source: (IPCC, 2007)

Fraction of Degradable Organic Carbon which Decomposes (DOCf)

Fraction of DOC_f default value of 0.5 in the 2006 IPCC Guidelines was used (Vol.5, Chapter 3, Page 3.13).

Constant k and half-life t1/2

The half-life value is the time taken for the DOC_m in waste to decay to half its initial mass. The constant k is related to $t_{1/2}$ by the equation:

$$k = \ln(2)/t_{1/2}$$

Equation 1-2: Relationship between half-life and reaction rate constant

Source: (IPCC, 2007)

For Ethiopia in the tropical dry zone default k and $t_{1/2}$ are shown Table 1-15 as provided by the 2006 IPCC guidelines Vol 5 Chapter 3, Tables 3.3 and 3.4.

Table 1-15: Constant k and half-life $t_{1/2}$

Waste Type	Constant (k)	Half-life $\mathbf{t_{1/2}}$
Paper and Cardboard	0.04	17
Food	0.06	12
Garden and Park Waste	0.05	14
Wood	0.02	35

Source: (IPCC, 2007)

Methane recovered R

There is mostly no methane recovery either for flaring or for energy use at the landfills in Ethiopia. The default value of R = zero is used (2006 IPCC Guidelines (Vol. 5, Chapter 3) was, therefore, used

Oxidation Factor (OX)

The open dumps in Ethiopia are not covered with aerated material hence the default value for OX of zero; according to the 2006 IPCC Guidelines (Volume 5, Chapter 3, Table 3.2) was used.

d. Category-specific QA/QC and Verification

Comparison of selected activity data and regional values was conducted. Analysis of activity data trends along with emission trends along the time series was also performed.

1.8 Uncertainty analysis

AD uncertainty was not available; hence uncertainty analysis was not performed. The output from the software is presented in Table 1-16.

Table 1-16: Uncertainty analysis

2006 IPCC Categories	Gas	1990 (Gg CO2 equivalent)	2017 (Gg CO2 equivalent)	Activity Data Uncertainty	Emission Factor Uncertainty	Combined Uncertainty (%)	Contribution to Variance by Category in 2017	Type A Sensitivity (%)	Type B Sensitivity (%)	Uncertainty in trend in national (%)	Uncertainty introduced by AD uncertainty (%)	Uncertainty introduced into the trend in total national emissions (%)
4.A - Solid Waste Disposal												
4.A - Solid Waste Disposal	CH4	227.16	850.28	0.00	0.00	0.00	0.00	0.53	0.17	0.00	0.00	0.00
4.B - Biological Treatment of Solid Waste												
4.B - Biological Treatment of Solid Waste	CH4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.B - Biological Treatment of Solid Waste	N2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.C - Incineration and Open Burning of Waste												
4.C.1 - Waste Incineration	CO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.C.1 - Waste Incineration	CH4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.C.1 - Waste Incineration	N2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.C.2 - Open Burning of Waste	CO2	63.71	130.16	0.00	0.00	0.00	0.00	0.17	0.03	0.00	0.00	0.00
4.C.2 - Open Burning of Waste	CH4	560.45	1145.04	0.00	0.00	0.00	0.00	1.50	0.22	0.00	0.00	0.00
4.C.2 - Open Burning of Waste	N2O	108.83	222.34	0.00	0.00	0.00	0.00	0.29	0.04	0.00	0.00	0.00
4.D - Wastewater Treatment and Discharge												
4.D.1 - Domestic Wastewater Treatment and Discharge	CH4	1056.24	2346.81	0.00	0.00	0.00	0.00	2.78	0.46	0.00	0.00	0.00
4.D.1 - Domestic Wastewater Treatment and Discharge	N2O	734.16	1631.20	0.00	0.00	0.00	0.00	1.93	0.32	0.00	0.00	0.00
4.D.2 - Industrial Wastewater Treatment and Discharge	CH4	0.17	84.34	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00
4.E - Other (please specify)		227.16	850.28	0.00	0.00	0.00	0.00	0.53	0.17	0.00	0.00	0.00

1.9 Recalculations

The 1994 recalculated figure for 4A (Solid waste) was higher by over 144% while the one for 2013 was higher by over 80%. Significant differences were obtained for open burning (4C) with the recalculations for both INC and SNC being significantly higher. The differences emanated from the use of more complete data, that calculating emissions from open burning for both rural and urban areas in the TNC.

Table 1-17: Recalculations of INC and SNC.

Category	INC			SNC		
	1994		% Difference	2013		% Difference
	Reported	Recalculated		Reported	Recalculated	
4A	114.97	280.8	144.25%	3582.07	703.92	-80.35%
4C	47.33	834.9	1664.06%	103.67	1359.3	1211.22%
4D	1706.12	263.16	-84.58%	3734.87	3630.36	-2.80%

1.10 Planned improvements

Table 1-18: Planned Improvements

Gap or constraint	Planned improvement	Timing
Default parameters on solid waste were used	Conduct a national waste survey determine the quantities of waste generated, composition and waste streams	
Collection of data was difficult due to lack of system for collecting, transmitting waste data	Set up waste sector activity data collection and transmission system	
Activity data and parameters used for estimating GHG emissions from the previous NCs were not available	Enhance the inventory archiving system	
Uncertainty analysis was not performed due to lack of data	Data providers to provide uncertainties when they submit data	

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ANNEXES

Annex A: Sources and Types of General Solid Wastes in Ethiopia

Source	Typical Waste Generators	Types Of Solid Wastes
Residential	Single and multi-family dwellings	Food wastes, paper, cardboard, plastics, including tin-plastic bags, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes, (e.g., bulky items, consumer electronics, batteries, oil, tires), and household hazardous wastes.
Industrial	Light and heavy manufacturing, fabrication, construction sites, and power plants	Housekeeping wastes, packaging, food wastes, construction and demolition materials, hazardous wastes, ashes, and special wastes.
Commercial	Sores, hotels, restaurants,	Paper, cardboard, plastics, wood,
	markets office buildings.	food wastes, metals, special wastes, hazardous wastes.
Institutional	Schools, hospitals, prisons, government centres.	Same as commercial.
Construction and demolition	New construction sites, road repair, renovation sites, demolition of buildings.	Wood, steel, concrete, dirt…etc.
Municipal Services	Street cleansing, landscaping, parks, beaches, other recreational areas, water and wastewater treatment plants	Street sweepings; landscape and tree trimmings; general wastes from parks, beaches, and other recreational areas, sludge.
Process	Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing	Industrial process wastes, scrap materials, off-specification products, slag, tailings.

Source: World Bank, May 1999.

Annex B: Housing units of urban areas by type of toilet facility by region

Region		All housing units	Has no toilet	Type of toilet facility: Flush Toilet		VIP Latrine		Pit Latrine	
				Private	Shared	Private	Shared	(Private)	Shared)
Country	No.	2,929,816	851,619	99,095	91,787	75,228	189,394	548,439	1,074,254
Tigray	No.	231,826	115,399	10,819	23,638	7,618	17,396	17,170	39,786
Afar	No.	43,762	24,663	984	795	1,277	2,861	3,760	9,422
Amhara	No.	591,428	219,987	7,448	11,096	8,242	21,447	98,629	224,579
Oromiya	No.	836,074	213,281	12,133	10,573	15,226	26,463	215,953	342,445
Somali	No.	91,241	46,086	1,193	1,886	3,192	5,541	13,684	19,659
BenShangul	No.	27,346	7,448	273	64	324	587	7,609	11,041
SNNPR	No.	342,224	71,067	4,484	4,088	6,554	10,322	113,918	131,791
Gambela	No.	19,080	10,752	314	185	285	994	1,781	4,769
Harari	No.	44,913	21,916	727	872	1,400	2,861	5,214	11,923
Addis	No.	628,986	90,206	58,123	35,684	28,903	95,520	62,009	258,541
Dire Dawa	No.	72,936	30,814	2,597	2,906	2,207	5,402	8,712	20,298

Source: CSA, 2008.

Annex C: Characteristics of wastewater effluents from selected industries in Ethiopia

Textile	**BOD**	**NH+4**	**NO-2**	**PO- -$_4$**	**pH**	**SS**	**Cd**	**Cr**	**Pb**
Edget Yarn	81.5	1.25	5	2.26	10.27	54.50	<0.1	<0.1	0.1
Nifas Silk Thread	10	0.15	3.1	1.69	8.01	86	<0.1	<0.1	0.2
Mean	45.8	0.7	4.1	2.0	9.1	70.3	<0.1	<0.1	0.2
Tanneries	**BOD**	**NH+4**	**NO-2**	**PO- -$_4$**	**pH**	**SS**	**Cd**	**Cr**	**Pb**
Addis Tannery	2428.	170.5	63.75	30.1	9.45	1350.5	<0.1	0.5	<0.1
Awash Tannery	914	52.65	6.25	6.18	3.805	664.5	<0.1	7	<0.1
Dire Tannery	2782	903.75	187.5	17.39	5.96	1615	0.4	1.5	3
Walia Tannery	1644.	73.5	17.64	11.26	10.45	997	<0.1	1.3	0.3
Mean	1942.	300.1	68.8	16.2	7.4	1156.8	0.4	2.6	1.7
Metal and non-metal	**BOD**	**NH+4**	**NO-2**	**PO- -$_4$**	**pH**	**SS**	**Cd**	**Cr**	**Pb**
Marble Industry	23.5	0.708	3.375	2.55	8.74	634.5	<0.1	<0.1	0.1
Addis Machine	16.6	0.41	6.7	0.1	8.24	31.5	<0.1	<0.1	<0.1
United Abilities	3.65	0.33	1.2	0.36	7.08	1.1	<0.1	<0.1	<0.1
Mean	14.6	0.5	3.8	1.0	8.0	222.4	<0.1	<0.1	0.1
Chemical industries	**BOD**	**NH+4**	**NO-2**	**PO- -$_4$**	**pH**	**SS**	**Cd**	**Cr**	**Pb**
Addis Tyre	13.5	2.20	1.6	0.55	8.27	13	<0.1	<0.1	<0.1
Addis Gas and Plastic	24.65	7.99	2.7	7.98	8.89	272.5	<0.1	<0.1	<0.1
Chora Gas and	85	0.48	0	2.9	10.1	27671	0.1	0.4	<0.1
Equatorial paint	575.5	15.38	0	0.28	8.305	3661	N.D.	N.D.	N.D.
Gullele soap	568	21.25	200	39.27	13.495	205.5	0.3	0.2	<0.1
Nifas silk paint	228.5	21.9	23.75	7.2	6.58	3612.5	<0.1	0.1	0.7
Mean	249.2	11.5	38.0	9.7	9.3	5905.8	0.2	0.2	0.7
Beverage factories	**BOD**	**NH+4**	**NO-2**	**PO- -$_4$**	**pH**	**SS**	**Cd**	**Cr**	**Pb**
Addis Soft Drinks	581.5	1.97	0	5.11	6.695	94	<0.1	<0.1	0.5
Awash Winery	3334	53.40	9	16	7.465	3249	<0.1	<0.1	<0.1
Moha Soft Drinks	407.5	8.9	13.5	19.65	12.315	336.5	<0.1	<0.1	0.3
National Alcohol and	185	154	0.2	49.88	7.91	2345	0.1	0.1	0.1
St. George Brewery	55	12.35	1.05	2.045	6.635	36	<0.1	<0.1	<0.1
Mean	913	46.1	4.8	18.5	8.2	1212.1	0.1	0.1	0.3
Food industries	**BOD**	**NH+4**	**NO-2**	**PO- -$_4$**	**pH**	**SS**	**Cd**	**Cr**	**Pb**
Addis Ababa Abattoirs	814.5	76	4.15	10.2	8.5	356	<0.1	0.1	<0.1
Addis Mojo Edible Oil	317	12.75	30	51.75	8.425	3706.5	<0.1	<0.1	<0.1
Mean	565.8	44.4	17.1	31.0	8.5	2031.3	<0.1	0.11	<0.1

Source: (Worku, 2011)

Annex D: Population

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Total	47.89	49.61	51.42	53.30	55.18	57.05	58.88	60.70	62.51	64.34	66.22	68.16	70.14	72.17	74.24	76.35
Rural	6.04	6.38	6.74	7.13	7.52	7.89	8.25	8.61	8.98	9.36	9.76	10.17	10.60	11.05	11.51	11.99
Urban	41.84	43.23	44.68	46.17	47.66	49.16	50.64	52.09	53.53	54.98	56.46	57.99	59.54	61.12	62.73	64.36

2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
78.49	80.67	82.92	85.23	87.64	90.14	92.73	95.39	98.09	100.84	103.60	106.40	109.22	112.08	114.96
12.48	13.00	13.69	14.41	15.18	15.99	16.84	17.72	18.64	19.59	20.58	21.61	22.68	23.79	24.94
66.01	67.67	69.23	70.82	72.46	74.15	75.89	77.67	79.46	81.25	83.02	84.79	86.55	88.29	90.02

Annex E: Waste sector emissions

Table A 1: CO_2 Emissions from Waste Sector

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
emissions (Gg)	63.71	66.00	68.41	70.90	72.57	75.02	77.43	79.82	82.20	83.63	86.08	88.59	91.17	93.80	95.36	98.06

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
emissions (Gg)	100.82	103.62	105.23	108.18	111.23	113.02	116.27	118.14	121.50	124.89	126.74	130.16	131.94	135.39	137.12

Table A 2: CH_4 emissions from waste sector

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
emissions (Gg)	80.50	83.46	89.49	89.80	92.70	95.93	99.14	102.31	105.48	108.29	111.59	114.98	118.48	122.05	125.26	128.91

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
emissions (Gg)	133.22	137.08	140.44	144.62	151.32	155.23	159.64	163.84	168.61	173.27	179.15	183.58	186.82	189.31	73.14

Table A 3: N_2O emissions from waste sector

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
emissions (Gg)	2.72	2.82	2.92	3.03	3.13	3.23	3.34	3.44	3.54	3.64	3.75	3.86	3.97	4.09	4.20	4.32

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
emissions (Gg)	4.44	4.56	4.68	4.81	4.95	5.08	5.23	5.37	5.52	5.67	5.82	5.98	6.13	6.29	0.76

Table A 4: Waste sector emissions by subcategory 1990-2019

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
4.A - Solid Waste Disposal	73.63	77.57	81.74	86.32	91.16	96.25	101.55	107.06	112.77	118.71	124.89	131.39	138.16	145.06	152.22	159.79
4.C.2 - Open Burning of Waste	732.98	759.34	787.10	815.75	834.90	863.15	890.92	918.36	945.75	962.20	990.34	1019.27	1048.92	1079.26	1097.14	1128.27
4.D.1 - Domestic Wastewater Treatment and Discharge	1790.40	1854.79	1922.59	1992.58	2063.07	2132.87	2201.50	2269.32	2337.00	2405.62	2475.97	2548.30	2622.43	2698.27	2775.62	2854.39
4.D.2 - Industrial Wastewater Treatment and Discharge	0.17	0.19	61.43	0.25	0.09	0.00	0.45	0.42	0.39	0.43	0.52	0.54	0.83	0.92	1.85	0.70

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
4.A - Solid Waste Disposal	167.64	175.85	184.46	193.70	203.54	213.91	223.17	233.06	243.59	254.76	266.59	279.09	292.27	306.13	320.71
4.C.2 - Open Burning of Waste	1159.94	1192.23	1210.78	1244.62	1279.75	1300.40	1337.72	1359.30	1397.90	1436.96	1458.18	1497.54	1518.07	1557.75	1577.62
4.D.1 - Domestic Wastewater Treatment and Discharge	2934.51	3016.20	3100.02	3186.67	3276.63	3370.10	3466.82	3566.23	3667.49	3769.98	3873.46	3978.02	4083.62	4190.33	0.00
4.D.2 - Industrial Wastewater Treatment and Discharge	11.77	11.81	10.21	11.62	62.66	63.49	61.20	64.34	64.75	61.20	95.45	84.34	61.20	0.13	0.00

Table A 5: Total GHG emissions from wastewater treatment

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
emissions (Gg)	1790.57	1854.97	1984.02	1992.84	2063.16	2132.87	2201.95	2269.74	2337.39	2406.05	2476.49	2548.85	2623.26	2699.19	2777.48	2855.09

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
emissions (Gg)	2946.28	3028.01	3110.23	3198.29	3339.29	3433.58	3528.02	3630.56	3732.24	3831.17	3968.92	4062.35	4144.82	4190.46

Table A 6: Precursors from open burning of waste

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
emissions (Gg)	247.7871	256.6978	266.082	275.7682	282.2422	291.7911	301.18	310.4579	319.7172	325.2776	334.7908	344.571	354.5941	364.8489	370.8927	381.4181

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
emissions (Gg)	392.1237	403.0405	409.3093	420.7503	432.6276	439.6074	452.2243	459.5181	472.5661	485.7717	492.9447	506.2502	513.193	526.6041