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ETHIOPIA NATIONAL GREENHOUSE GAS INVENTORY FOR THE INDUSTRIAL PROCESSES AND PRODUCT USE SECTOR: 1990 - 2019

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Acronyms

AR2	IPCC Second Assessment Report
AR5	IPCC Fifth Assessment Report
CCIIDI	Chemical and Construction Industry Inputs Development Institute
CH_4	Methane
CKD	Cement Kiln Dust
CO	Carbon monoxide
CO_2	Carbon dioxide
CORINAIR	Core Inventory of Air Emissions
CSA	Central Statistical Agency
EAF	Electric Arc Furnace
EF	Emission Factor
EFCCC	Environment, Forest and Climate Change Commission
ESED	Environment, Safety and Energy Directorate
FBI	Food and Beverages Industry
GCB	Gas circuit breakers
GHG	Greenhouse Gas
GIL	gas-insulated lines
GIS	Gas-insulated switchgear
GIT	Gas-insulated transformers
GWP	Global warming potentials
HAPs	hydrocarbon aerosol propellant
HFCs	Hydroflurocarbons
HFO-	Heavy fuel oil
INC	Initial National Communication
IPPU	Industrial Processes and Product Use
Kt	kilotonnes
MIDI	Metal Industry Development Institute
MOTI	Ministry of Trade and Industry
NA	Not Applicable
NE	Not Estimated
N_2O	Nitrous Oxide
NEUs	Non-Energy Use of Fuels

NMVOCs	Non-methane Volatile Organic Carbons
NOx	Nitrogen Oxides
ODU	Oxidation during use
OPC	Ordinary Portland cement
PFCs	Perfluorocarbons
PPC	Portland Pozzolana Cement
PPI	Pulp and Paper Industry
QA	Quality Assurance
QC	Quality Control
R & AC	Refrigeration and Air Conditioning
SF_6	Sulphur hexafluoride
SNC	Second National Communication
SO_2	Sulphur dioxide
TNC	Third National Communication

1 Overview of sector

1.1 Ethiopia industry overview

The Ethiopian manufacturing industry has been recently growing. The cement subsector has been one of the fastest growing owing to its key role in the growth of construction and infrastructure development in the country. During the last five years, the industry sector GDP (value added) has witnessed an annual average growth rate of 20%. Within the industry sector, medium and large-scale manufacturing industries registered average growth rate of 19.2% per annum and micro and small industries registered an average growth rate of 4.1% per annum. At the end of the Ethiopian growth and transformation plan period (2015-2020), the share of the industry sector in overall GDP reached 15.1% (manufacturing 4.8%, construction 8.5%, electric and water 1.0% and mining 0.8%). Some interventions have been proposed to reduce emissions coming from the sector in the coming years. According to the updated 2021 NDC these interventions will reduce emission levels to 22.6Mt CO_2eq in 2030 in the conditional pathway (FDRE, 2021). One of the policies implemented by the Ethiopian Government to mitigate process related emissions in the cement sector is clinker substitution while saving from increased nitrogen use efficiency.

1.2 Overview of the GHG Emissions

In Ethiopia, Greenhouse Gas (GHG) emissions from Industrial Processes and Product Use (IPPU) are mainly generated from mineral industries, although there are a wide variety of industrial activities. Cement production is the main source of GHGs from mineral production. The other sources include lime production, glass production and ceramics. The main ceramics produced include clay bricks, as well as floor and wall tiles. Data on soda ash production was only available for 2006 to 2019. From iron and steel production (2C1), the only source of GHG reported was from secondary steel production from electric arc furnaces. Ethiopia does not currently produce primary steel and ferrochrome. The emissions from non-energy use of fuels (2D) mainly came from the use of waxes and petroleum jelly. The manufacture of electronics (2E) does not occur in Ethiopia. GHG emissions from the ozone depleting chemicals substitutes, foam blowing (2F2) and fire protection (2F3) were reported in the TNC (Third National Communication). Although activity data on refrigeration and air conditioning equipment imported and manufactured locally was compiled, the emitted GHGs could not be calculated since data on the gases charged in the equipment were not provided. The GHG emissions from manufacture and use of electrical equipment were not reported owing to data unavailability. Although the methodology for estimating NMVOCs from food and beverages (2H2) is not provided in the 2006 IPCC Guidelines, the EMP/EMEP 2019 emissions guidebook was used to calculate the GHGs. The main gas, therefore, reported was carbon dioxide (CO_2). Hydrofluorocarbons (HFCs) from foam blowing and fire extinguishers were only reported for the years from 2000.

The main data sources were the Central Statistical Agency (CSA), The Ethiopian Customs, the Chemical and Construction Industry Inputs Development Institute (CCIIDI), Metals Industries Development Institute (MIDI) and EFCCC. The emission factors were obtained from the 2006 IPCC Guidelines (IPCC, 2006), except for those for food and beverages that were obtained from EMEP/EEA Guidelines for 2019 (EMEP/EEA, 2019).

1.3 Overview of GHG Emissions in 2017

In 2017 a total of 4769.76 Gg of greenhouse gas (GHG) emissions were emitted from the industrial processes and product use sector in Ethiopia. The bulk of these emissions were from mineral industry contributing 3835.75Gg followed by Non-energy Products from fuels and solvent use contributing 808.81Gg and lastly metal industry with 43.03Gg .Looking into the Mineral Industry the most dominating production was cement production with 3567.84Gg, Lime production with 246.17Gg and Glass Production with 1.24Gg.This information is depicted in Table ***1-2***.

1.4 Overview of methodological issues

In the Initial National Communication (INC), the GHG emissions were reported for the year 1994 and the Revised 1996 IPCC Guidelines were used. Tier 1 methodologies were used for the INC and Second National Communication (SNC). In the SNC, tier 1 methodology was also used for all categories, owing to data unavailability. However, the GHG emissions for cement production from the SNC were not available and it was not possible to recalculate the GHG emissions for the whole time series. The Global Warming Potentials (GWP) from the Intergovernmental on Climate Change (IPCC) Second Assessment report (AR2) (IPCC, 1995) was used in the TNC.

In the SNC the estimated emissions were for the years 1994 to 2013 and covered the production of cement, lime glass and soda ash. In the TNC most data covered the years 1990 to 2019.

1.5 Global warming potentials

Table 1-1 presents the 100-year time horizon GWP relative to CO_2. This table is adapted from the IPCC AR2.

Table 1-1: Global warming potentials from the IPCC AR2

Name of gas	Chemical formula	Global warming potential (GWP)
Carbon dioxide	CO_2	1
Methane	CH_4	21
Nitrous oxide	N_2O	310
Hydrofluorocarbons	HFC-245fa (CHF2CH2CF3)	1030

Source; (IPCC, 1995)

The GHG emissions for the reporting year, 2017, are presented in Table **1-2**

Table 1-2: GHG emissions in 2017 in units of Gg

Categories	(Gg)			CO_2 Equivalents (Gg)						
	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NOx	CO	NMVOCs	SO_2
2 - Industrial Processes and Product Use	4688.40	0.00	0.00	81.36	0.00	0.00			1909.59	0.0026
2.A - Mineral Industry	3835.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00005	0.00
2.A.1 - Cement production	3567.84	NE	NA	NA	NA	NA	NE	NE	NE	0.00
2.A.2 - Lime production	246.17	NE	NA	NA	NA	NA	NE	NE	NE	NE
2.A.3 - Glass Production	1.24	NE	NA	NA	NA	NA	NE	NE	0.00005	NE
2.A.4 - Other Process Uses of Carbonates	20.50	NE	NA	NA	NA	NA	NE	NE	NE	NE
2.A.4.a - Ceramics	20.50	NE	NA	NA	NA	NA	NE	NE	NE	NE
2.A.4.b - Other Uses of Soda Ash	NE	NE	NA	NA	NA	NA	NE	NE	NE	NE
2.A.4.c - Non-Metallurgical Magnesia Production	NO	NO	NA	NA	NA	NA	NO	NO	NO	NO
2.A.4.d - Other	NO	NO	NA	NA	NA	NA	NO	NO	NO	NO
2.A.5 - Other	NO	NO	NO	NA	NA	NA	NO	NO	NO	NO
2.B - Chemical Industry	0.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.B.1 - Ammonia Production	NO	NO	NO	NA	NA	NA	NO	NO	NO	NO
2.B.2 - Nitric Acid Production	NO	NO	NO	NA	NA	NA	NO	NO	NO	NO
2.B.3 - Adipic Acid Production	NO	NO	NO	NA	NA	NA	NO	NO	NO	NO
2.B.4 - Caprolactam, Glyoxal and Glyoxylic Acid Production	NO	NO	NO	NA	NA	NA	NO	NO	NO	NO
2.B.5 - Carbide Production	NO	NO	NO	NA	NA	NA	NO	NO	NO	NO
2.B.6 - Titanium Dioxide Production	NO	NO	NO	NA	NA	NA	NO	NO	NO	NO
2.B.7 - Soda Ash Production	0.81	NE	NE	NA	NA	NA	NE	NE	NE	NE
2.B.8 - Petrochemical and Carbon Black Production	NO	NO	NO	NA	NA	NA	NO	NO	NO	NO
2.B.8.a - Methanol	NO	NO	NO	NA	NA	NA	NO	NO	NO	NO
2.B.8.b - Ethylene	NO	NO	NO	NA	NA	NA	NO	NO	NO	NO
2.B.8.c - Ethylene Dichloride and Vinyl Chloride Monomer	NO	NO	NO	NA	NA	NA	NO	NO	NO	NO
2.B.8.d - Ethylene Oxide	NO	NO	NO	NA	NA	NA	NO	NO	NO	NO
2.B.8.e - Acrylonitrile	NO	NO	NO	NA	NA	NA	NO	NO	NO	NO
2.B.8.f - Carbon Black	NE	NE	NE	NA	NA	NA	NE	NE	NE	NE
2.B.9 - Fluorochemical Production							NE	NE	NE	NE
2.B.9.a - By-product emissions (4)	NA	NA	NA	NO	NO	NO	NO	NO	NO	NO
2.B.9.b - Fugitive Emissions (4)	NA	NA	NA	NO	NO	NO	NO	NO	NO	NO
2.B.10 - Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.C - Metal Industry	43.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	80.68	0.00
2.C.1 - Iron and Steel Production	43.03	NE	NE	NA	NA	NA	NE	NE	80.68	NE
2.C.2 - Ferroalloys Production	NO	NO	NO	NA	NA	NA	NO	NO	NO	NO
2.C.3 - Aluminium production	NO	NO	NA	NA	NO	NA	NO	NO	NO	NO
2.C.4 - Magnesium production	NO	NA	NA	NO	NO	NO	NO	NO	NO	NO
2.C.5 - Lead Production	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.C.6 - Zinc Production	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.C.7 - Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.D - Non-Energy Products from Fuels and Solvent Use	808.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0000042	0.00
2.D.1 - Lubricant Use	0.13	NA	NA	NA	NA	NA	NE	NE	0.00000	NE
2.D.2 - Paraffin Wax Use	5.68	NE	NE	NA	NA	NA	NE	NE	NE	NE
2.D.3 - Solvent Use	NA	NA	NA	NA	NA	NA	NE	NE	NE	NE
2.D.4 - Other (Asphalt and Bitumen)	803.00	NE	NE	NA	NA	NA	NE	NE	NE	NE
2.E - Electronics Industry										
2.E.1 - Integrated Circuit or Semiconductor	NO	NA	NO	NO	NO	NO	NO	NO	NO	NO
2.E.2 - TFT Flat Panel Display	NA	NA	NA	NO	NO	NO	NO	NO	NO	NO

Categories	(Gg)			CO_2 Equivalents (Gg)						
	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NOx	CO	NMVOCs	SO_2
2.E.3 - Photovoltaics	NA	NA	NA	NO	NO	NO	NO	NO	NO	NO
2.E.4 - Heat Transfer Fluid	NA	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.E.5 - Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.F - Product Uses as Substitutes for Ozone Depleting Substances	0.00	0.00	0.00	81.36	0.00	0.00			0.00	0.00
2.F.1 - Refrigeration and Air Conditioning										
2.F.1.a - Refrigeration and Stationary Air Conditioning	NE	NA	NA	NE	NE	NA	NE	NE	NE	NE
2.F.1.b - Mobile Air Conditioning	NE	NA	NA	NE	NE	NA	NE	NE	NE	NE
2.F.2 - Foam Blowing Agents	NE	NA	NA	2.78	NE	NA	NE	NE	NE	NE
2.F.3 - Fire Protection	NE	NA	NA	78.58	NE	NA	NE	NE	NE	NE
2.F.4 - Aerosols	NA	NA	NA	NE	NE	NA	NE	NE	NE	NE
2.F.5 - Solvents	NA	NA	NA	NE	NE	NA	NE	NE	NE	NE
2.F.6 - Other Applications	NE	NE	NE	NE	NE	NA	NE	NE	NE	NE
2.G - Other Product Manufacture and Use										
2.G.1 - Electrical Equipment										
2.G.1.a - Manufacture of Electrical Equipment	NA	NA	NA	NA	NE	NE	NE	NE	NE	NE
2.G.1.b - Use of Electrical Equipment	NA	NA	NA	NA	NE	NE	NE	NE	NE	NE
2.G.1.c - Disposal of Electrical Equipment	NA	NA	NA	NA	NE	NE	NE	NE	NE	NE
2.G.2 - SF6 and PFCs from Other Product Uses	NA	NA	NA	NA	NE	NE	NE	NE	NE	NE
2.G.2.a - Military Applications	C	C	C	C	C	C	C	C	C	C
2.G.2.b - Accelerators	NA	NA	NA	NA	NE	NE	NE	NE	NE	NE
2.G.2.c - Other	NA	NA	NA	NA	NE	NE	NE	NE	NE	NE
2.G.3 - N2O from Product Uses	NA	NA	NE	NA	NA	NA	NE	NE	NE	NE
2.G.3.a - Medical Applications	NA	NA	NE	NA	NA	NA	NE	NE	NE	NE
2.G.3.b - Propellant for pressure and aerosol products	NA	NA	NE	NA	NA	NA	NE	NE	NE	NE
2.G.3.c - Other	NA	NA	NE	NA	NA	NA	NE	NE	NE	NE
2.G.4 - Other	NE	NE	NA	NE	NA	NA	NE	NE	NE	NE
2.H - Other	NE	NE	NE	NA	NA	NA	NE	NE	1828.912	NE
2.H.1 - Pulp and Paper Industry	NE	NE	NA	NA	NA	NA	NE	NE	NE	NE
2.H.2 - Food and Beverages Industry	NE	NE	NA	NA	NA	NA	NE	NE	1828.912	NE
2.H.3 - Other	NE	NE	NE	NA	NA	NA	NE	NE	NE	NE

In 2017, CO_2 emissions accounted for the bulk (98.29%) of the GHG emissions from IPPU. HFCs contributed below 2%. Figure 1-1 presents the contribution by gas to IPPU GHG emissions in 2017.

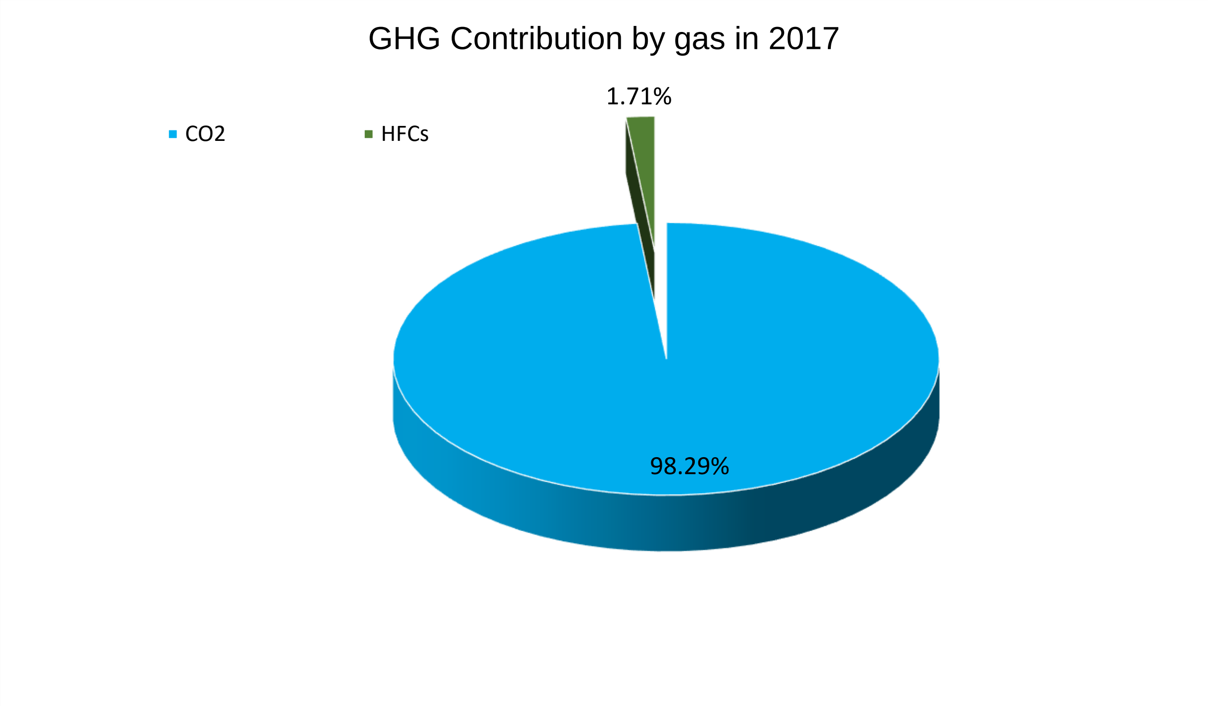

Figure 1-1: Contribution by gas

GHG emissions contribution by Sub Category

Figure 1-2 presents GHG emissions by sub category in the IPPU sector for the year 2017. About 79% of the emissions were from the Mineral Industry (2A) sub category mainly due to cement production which is the largest emitting Industry in Ethiopia while the least emissions were from the Metal Industry (2C) amounting to 1% of the total emissions.

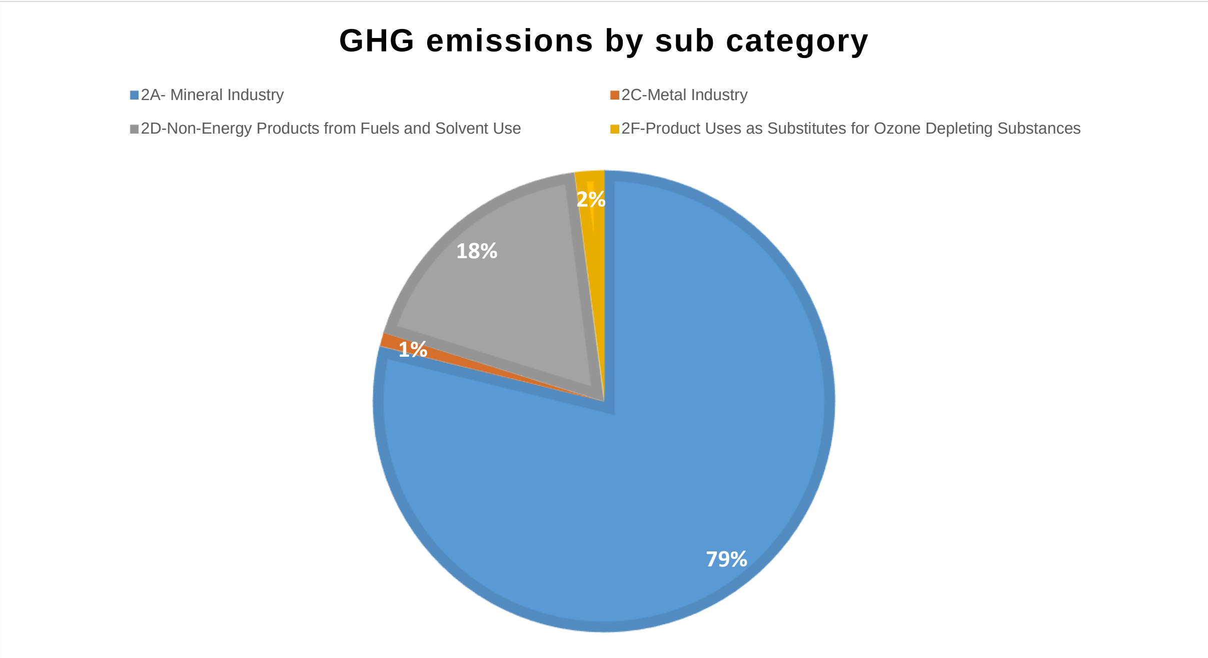

Figure 1-2: Contribution by Sub Category

1.6 Trends in total IPPU GHG emissions

There was a steady rise in GHG emissions from just above 380ktCO_2eq in 2000 to 4769.76ktCO_2eq in 2017. The steady rise in CO_2 emissions since 2006 was largely driven by the growth in industry activities, mainly cement production. Cement and ceramics production were the main sources of GHG emissions from 1990. The increase in the number of cement companies in response to the accelerated growth in the construction industry largely contributed to the increase in CO_2 from the cement sector. From 2000 to 2006 cement production was the main source of GHGs, contributing over 90% of the emissions during that period. The use of fuels for non-energy purposes has also contributed to the GHG emissions since 2007, accounting for between 16% to over 30% in some years, of CO_2 emissions from IPPU for the period 2007 to 2019. GHG emissions from iron and steel remained below 1% for the whole time series. Fire suppression chemicals use also contributed to the GHG emissions, accounting for a small fraction of GHG emissions throughout the time series. Emissions from the IPPU sector for the whole time series are presented in Figure 1-3.

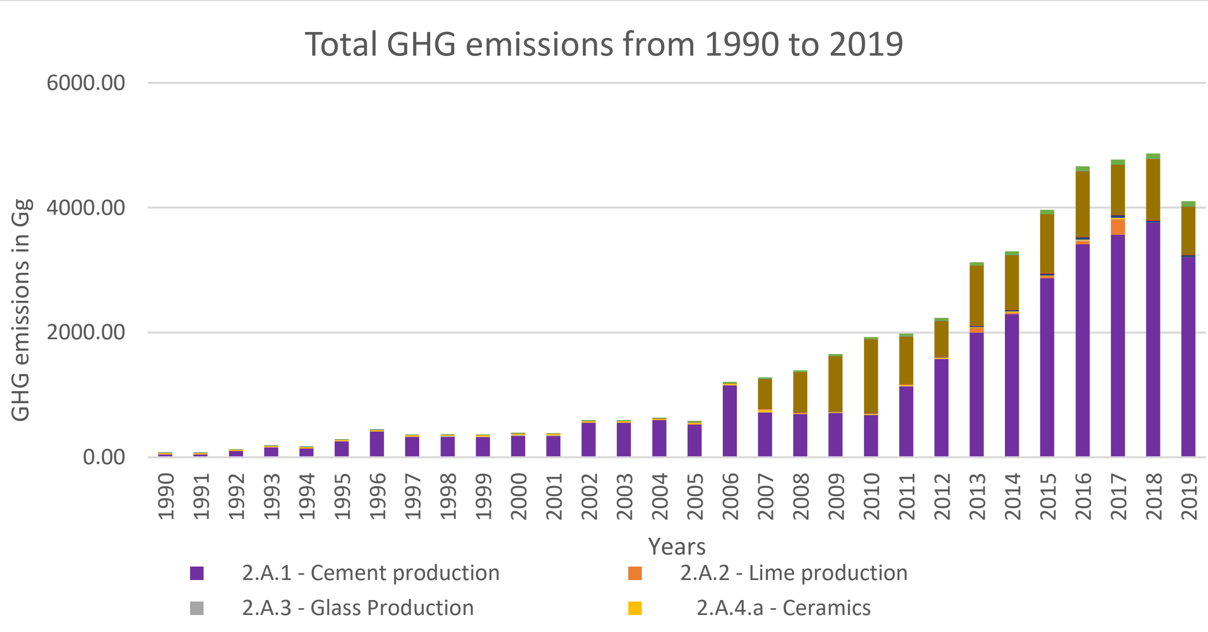

Figure 1-3: Total GHG emissions from IPPU from 1990 to 2019

The graph shows a gradual increase in GHG emission from 1990 up to 2005 as the emissions remained below the 1000Gg mark. A sharp increase in GHG emissions was observed from 2006 up to 2018 followed by a decline in 2019. The change from 1990 to 2019 level indicates approximately 99% increase in GHG emissions.

1.7 Key categories

Key category analysis was performed for the IPPU sector for the purpose of demonstration. Key categories from IPPU should, therefore, be identified once the full inventory including all sectors has been compiled. In 2017 cement production, non-energy products from fuels and solvent use, as well as lime production were the key categories by level, with cement contributing the bulk of the GHG emissions at 74.81%, followed by Non-Energy Products from Fuels with 16.96%. The key category by level is shown in **Table *1-3***.

Table 1-3: Key category in 2017 by level

IPCC Category code	IPCC Category	Greenhouse gas	2017 Ex,t (Gg CO_2Eq)	|Ex,t| (Gg CO_2Eq)	Lx,t	Cumulative Total of Column F
2.A.1	Cement production	CO_2	3567.84	3567.84	74.81%	74.81%
2.D	Non-Energy Products from Fuels and Solvent Use	CO_2	808.81	808.81	16.96%	91.77%
2.A.2	Lime production	CO_2	246.17	246.17	5.16%	96.94%
2.F.3	Fire Protection	HFCs, PFCs	78.58	78.58	1.65%	98.58%
2.C.1	Iron and Steel Production	CO_2	43.03	43.03	0.90%	99.49%
2.A.4	Other Process Uses of Carbonates	CO_2	20.50	20.50	0.43%	99.92%
2.F.2	Foam Blowing Agents	HFCs (HFCs)	2.78	2.78	0.06%	99.97%
2.A.3	Glass Production	CO_2	1.24	1.24	0.03%	100.00%

When considering key categories by trend, cement production remains the main contributor to the trends in GHG emissions between 2000 and 2017. The key category by trend is shown in Table 1-4.

Table 1-4: Key category by trend 2000 to 2017

IPCC Category code	IPCC Category	Greenhouse gas	2000 Year Estimate Ex0 (Gg CO_2eq)	2017 Year Estimate Ext (Gg CO_2eq)	Trend Assessment (Txt)	% Contribution to Trend
2.A.1	Cement production	CO_2	343.40	3567.84	0.06	0.87%
2.D	Non-Energy Products from Fuels and Solvent Use	CO_2	0.21	808.81	0.03	0.38%
2.A.2	Lime production	CO_2	6.07	246.17	0.01	0.10%
2.A.4	Other Process Uses of Carbonates	CO_2	25.68	20.50	0.00	0.05%
2.F.3	Fire Protection	HFCs, PFCs	6.09	78.58	0.00	0.02%
2.C.1	Iron and Steel Production	CO_2	0.41	43.03	0.00	0.02%
2.A.3	Glass Production	CO_2	7.69	1.24	0.00	0.02%
2.F.2	Foam Blowing Agents	HFCs (HFCs)	0.38	2.78	0.00	0.00%

1.8 Summary of methodologies

Tier 1 methodology was used on all categories due to data availability issues. The summary of the methodologies used is presented in Table 1-5.

Table 1-5: Summary of methodologies

		Emission Factor									
IPCC source category	Activity data source	CO_2	CH_4	N_2O	HFCs	PFCs	SF6	NOx	CO	NMVOCs	SO_2
2.A - Mineral Industry											
2.A.1 - Cement production	CCIIDI, CSA	D	NE	N/A	N/A	N/A	N/A	NE	NE	NE	D
2.A.2 - Lime production	CSA	D	NE	N/A	N/A	N/A	N/A	NE	NE	NE	NE
2.A.3 - Glass Production	CSA	D	NE	N/A	N/A	N/A	N/A	NE	NE	D	NE
2.A.4.a - Ceramics	CSA	D	NE	N/A	N/A	N/A	N/A	NE	NE	NE	NE
2.B.7 - Soda Ash Production	CCIIDI	D	N/A	N/A	N/A	N/A	N/A	NE	NE	NE	NE

		Emission Factor									
IPCC source category	**Activity data source**	**CO_2**	**CH_4**	**N_2O**	HFCs	PFCs	SF6	NOx	CO	NMVOCs	SO_2
2.C - Metal Industry											
2.C.1 - Iron and Steel Production	CSA	D	NE	NE	N/A	N/A	N/A	NE	NE	D	NE
2.D.1 - Lubricant Use	CSA, Customs	D	N/A	N/A	N/A	N/A	N/A	NE	NE	D	NE
2.D.2 - Paraffin Wax Use	CSA, Customs	D	NE	NE	N/A	N/A	N/A	NE	NE	NE	NE
2.D.3 - Solvent Use	NE	NA	N/A	N/A	N/A	N/A	N/A	NE	NE	D	NE
2.D.4 - Other (please specify)	CSA, Customs	D	NE	NE	N/A	N/A	N/A	NE	NE	NE	NE
2.F.2 - Foam Blowing	Ozone	NE	NA	NA	D	NE	NA	NE	NE	NE	NE
2.F.3 - Fire Protection	Ozone	NE	NA	NA	D	NE	NA	NE	NE	NE	NE
2.F.4 - Aerosols	NE	NE	NA	NA	NE	NE	NA	NE	NE	NE	NE
2.F.5 - Solvents	NE	NE	NA	NA	NE	NE	NA	NE	NE	NE	NE
2.G - Other Product Manufacture and Use	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.H.2 - Food and Beverages Industry	National from CSA	NE	NE	N/A	N/A	N/A	N/A	NE	NE	D	NE

D- Default, NA- Not Applicable, NE- Not Estimated, NO- Not Occurring,

In 1994, in the INC, Ethiopia reported 310 Gg of CO_2, 2.3Gg of NMVOCs and 0.2Gg of SO_2. In the SNC in 2013, IPPU contributed 1,757.9984Gg CO_2eq, accounting for 1% of the national totals. The recalculated GHGs are presented in Table 1-6 **Table *1-6*: CO2 emissions comparisons**. There was decrease of over 45% in the total recalculated GHG emissions for INC, whereas the recalculated GHG emissions for SNC increased by over 78%. The INC and SNC used the Revised 1996 IPCC Methodologies while in the TNC the 2006 IPCC methodologies were used. The number of categories reported increased from one in the INC, to three in the SNC and then 5 in the TNC.

Table 1-6: CO_2 emissions comparisons

	Reported in the INC	**Reported in the SNC**	**Recalculated in the TNC**		**TNC**	**% Difference (TNC-INC)**	**% Difference TNC-SNC)**
	1994	2013	1994	2013	2017		
2. Industrial Processes	**310**	1,757.	**167.81**	3127.83	4768.95	**-45.87%**	**78.02%**
2.A - Mineral Industry	310	917.17672	165.55	2084.882523		-46.60%	127.32%
2.B - Chemical Industry	0	0.1820915	0.0	0.0		0.0	-100.00%
2.C - Metal Industry	0	840.6396	**0.71**	17.7687136	43.0315536	0.0	-97.89%
2.D - Non-Energy Products from Fuels and Solvent Use (6)	0		0.00	883.9653513	808.8105671	0.0	0.0
2.E - Electronics Industry	NO	NO	NO	NO	NO		
2.F - Product Uses as Substitutes for Ozone Depleting Substances	NE		1.69	70.12736098	81.36		
2.G - Other Product Manufacture and Use	NE						
2.H - Other	NE						

1.9 Uncertainty assessment

Uncertainty assessment was done using error propagation and the calculations were done in the software. The results of the analysis are shown in

Table ***1-7***. Activity data uncertainty was obtained from the data providers while default emission factor uncertainties were obtained from the 2006 IPCC Guidelines and computed in the IPCC GHG inventory software. Cement production had the highest contribution to IPPU uncertainty.

Table 1-7: Uncertainty assessment

2006 IPCC Categories	Gas	2000 emissions or removals (Gg CO_2 eq)	2017 emissions or removals (Gg CO_2 eq)	Activity Data Uncertainty (%)	Emission Factor or Uncertainty (%)	Combined Uncertainty (%)	Contribution to Variance by Category in 2017	Type A Sensitivity (%)	Type B Sensitivity (%)	Contribution of emission factor uncertainty (%)	Contribution of activity data uncertainty (%)	Uncertainty introduced into the trend in total national emissions (%)
2.A - Mineral Industry												
2.A.1 - Cement production	CO_2	343.40	3567.84	2.50	0.00	2.50	0.00	0.21	0.12	0.00	0.42	0.18
2.A.2 - Lime production	CO_2	6.07	246.17	1.00	0.00	1.00	0.00	0.01	0.01	0.00	0.01	0.00
2.A.3 - Glass Production	CO_2	7.69	1.24	5.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00
2.C - Metal Industry	CO_2											
2.C.1 - Iron and Steel Production	CO_2	0.41	43.03	2.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00
2.D - Non-Energy Products from Fuels and Solvent Use	CO_2											
2.D.1 - Lubricant Use	CO_2	0.00	0.13	10.00	0.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00
2.D.2 - Paraffin Wax Use	CO_2	0.00	5.68	10.00	0.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00
2.D.4 - Other (please specify)	CO_2	0.21	803.00	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.00
2.F - Product Uses as Substitutes for Ozone Depleting Substances												
2.F.2 - Foam Blowing Agents	CH2FCF3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

1.10 GHG emissions by source category

1.10.1 2 A Mineral Industry

The total GHG emissions from IPPU for the period 1990 to 2019 were dominated by CO_2 emissions from Mineral Industry (2A). The CO_2 emissions from mineral industry increased from around 72.85Gg in 1990 to 3205.99Gg in 2019 (Figure 1-4). Cement production was the main source of the CO_2 emissions owing to the dominance and recent growth of the cement industry in Ethiopia. CO_2 emissions from lime production are the second to cement. There has been an increase in CO_2 emissions from the non-energy use of fuels since 2007.

Paraffin waxes and petroleum jelly use were the main drivers for the CO_2 emissions from the non-energy use of fuels.

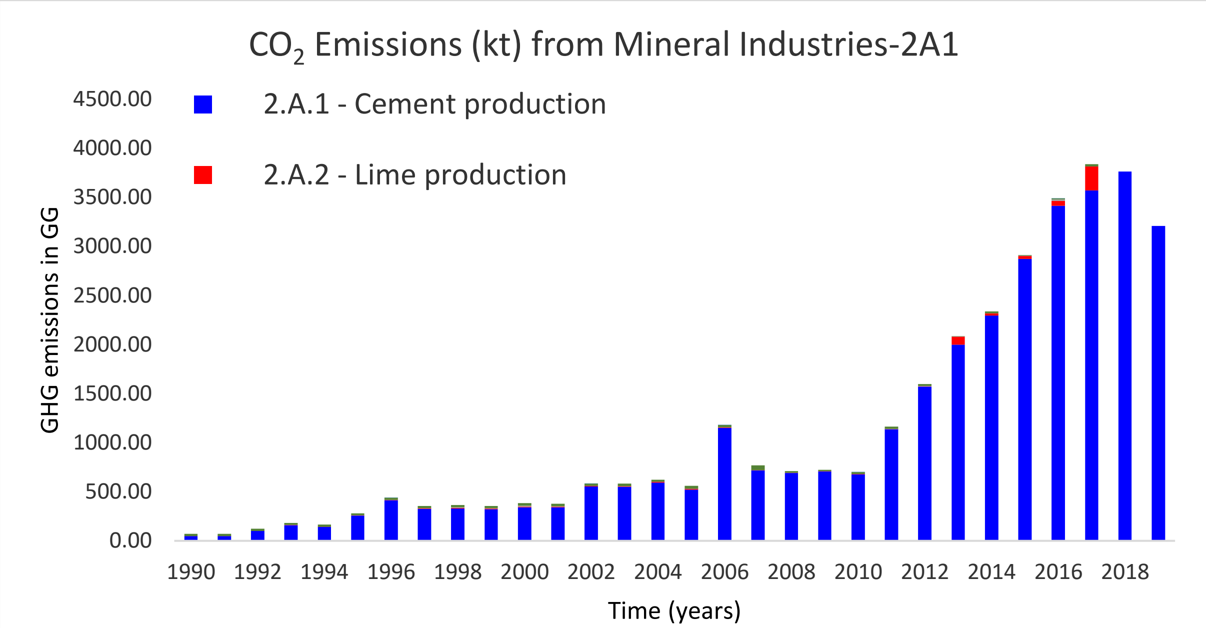

Figure 1-4: CO_2 emissions from Mineral industries -2A

The graph shows a gradual increase in CO_2 Emissions from 1990 to 2010 though characterized with some spikes in 1996 and 2006. From 2011 to 2017 there was a sharp increase in the CO_2 Emissions followed by a gradual decline in 2018 to 2019. An increase of about 99.0% from 1990 $C0_2$ emissions levels to the 2017 levels were noted.

1.10.1.1 2 A 1 Cement Production

Cement production is the major contributor of GHG emissions from IPPU in Ethiopia. The number of companies has been growing rapidly in recent years resulting in a corresponding steady rise in GHGs from cement production. Close to 100% of the clinker is produced locally. The emissions from cement production since 1990 are shown in Figure 1-5. The steady rise in emissions since 2011 is attributed to the increased cement output owing to the increase in cement companies from 2000 to 2018. In 2018, the cement industry started to mitigate CO_2 emissions from the industry by reducing clinker in Portland Pozzolana Cement (PPC) from 78% clinker to 70% which resulted in a decrease in GHGs from 2018 to 2019.

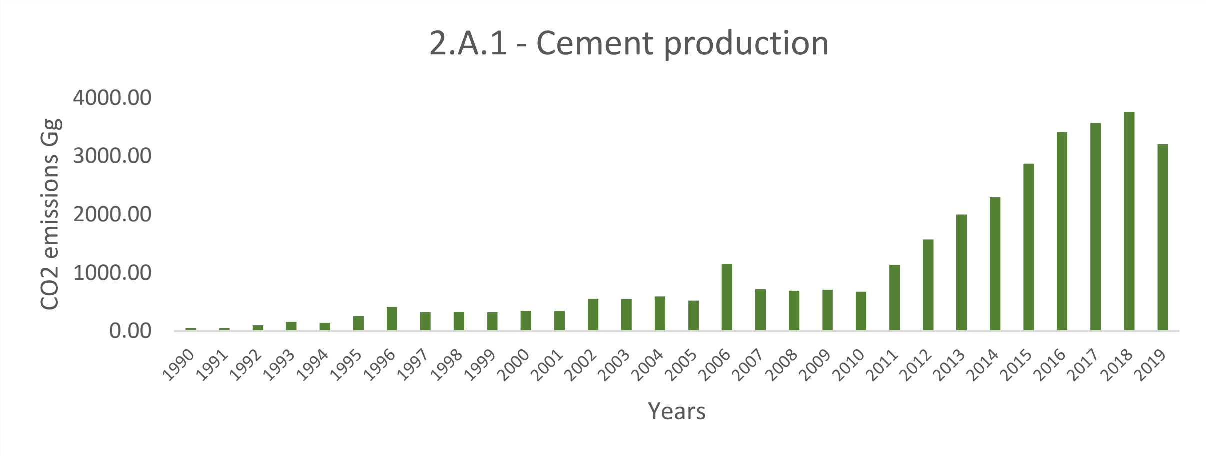

Figure 1-5:CO_2 emissions from cement production

The graph indicates a steady increase in $C0_2$ emissions in cement production from 1990 to 2010 marked by some spikes in 1996 and 2006. A sharp rise was experienced from 2011 to a peak of 3761.05Gg $C0_2$eq representing about 99% increase from the 1990 figure of 47.47Gg CO_2eq. In the year 2019, there was sharp decline of about 14.7%.

a. Methodological issues

Only tier 1 methodology was used. Clinker production data was obtained from CCIIDI for the years 2017 to 2019. In that case, Tier 2 data was available for one year in the cement sector, making it impossible to apply it in the calculations for the whole time series.

b. Activity data

Table 1-8: presents data for OPC and PPC cement production (in million tonnes) from 1990 to 2019. Data for 1990 to 1992 were missing and the gaps were filled by trend extrapolation.

Table 1-8: **Cement production data**

Year (G.C)	**Domestic Cement production in million tons**		
	OPC	**PPC**	**TOTAL**
1990/1	0.03	0.09	0.11
1991/2	0.03	0.09	0.11
1992/3	0.06	0.18	0.24
1993/4	0.09	0.28	0.38
1994/5	0.11	0.35	0.46
1995/6	0.15	0.46	0.61
1996/7	0.44	0.51	0.66
1997/8	0.189	0.59	0.77
1998/9	0.191	0.59	0.78
1999/2000	0.188	0.58	0.77
2000/1	0.199	0.62	0.82
2001/2	0.199	0.62	0.82
2002/3	0.19	1.15	1.34
2003/4	0.28	1.14	1.42

Year (G.C)	Domestic Cement production in million tons		
	OPC	PPC	TOTAL
2004/5	0.25	1	1.25
2005/6	0.57	2.18	2.75
2006/7	0.3	1.42	1.72
2007/8	0.28	1.38	1.66
2008/9	0.33	1.36	1.69
2009/10	0.32	1.3	1.62
2010/11	0.54	2.18	2.72
2011/12	0.93	2.8	3.76
2012/13	1.12	3.63	4.73
2013/14	1.22	4.25	5.47
2014/15	1.4	5.46	6.86
2015/2016	1.63	6.53	8.16
2016/2017	1.71	6.82	8.52
2017/2018	1.68	6.72	8.41
2018/2019	1.64	6.58	8.23
2019/2020	1.66	6.67	8.33

Source; (CCIIDI, 2021)

Clinker production for PPC used a 0.78 clinker fraction from 1990 to 2017, however, for 2018 and 2019, the clinker fraction reduced to 0.70 due to the introduction of Pumice in clinker production, a measure to reduce emissions from cement production.

Table 1-9: Emission Factor for Cement production

Parameter		Source	Comment
Clinker production	0.93-OPC 0.78-PPC (1990 to 2017) 0.70 -PPC (2018 and 2019)	CCIIDI	
Emission factor	0.51	Default	Default emission factor was applied
CKD correction factor	1.02		

Table 1-10: Clinker production data

YEAR	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
PPC	66436.548	96284.8519	139543.264	222197.3758	273645.392	359006.519	396260.678	456473.789	461197.808	451910.637
OPC	24815.3042	35964.209	52122.042	82994.91255	102211.717	134095.709	148010.84	170501.574	172266.084	168797.15

2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
480611.242	1107600	219618362	889200	780000	1700400	1107600	1076400	1060800	1014000
9,000	90,000	171,000	252,000	252,000	513,000	270,000	252,000	297,000	288,000

2010	2011	2012	2013	2014	2015	2016	2017	2018	2019

1700400	2184000	2831400	3315000	4258800	5093400	5319600	5241600	4606000	4669000
486,000	837,000	2,541,000	2,541,000	1,098,000	1,467,000	1,260,000	1,467,000	1,539,000	1,539,000

Sources; (CSA, 2021) ***and*** (CCIIDI, 2021)

The emission factor for CO_2 emissions was obtained from the 2006 IPCC Guidelines. Cement kiln dust is recycled and the average recycling ration as provided by the CCIIDI (CCIIDI, 2021) and cement kiln dust correction factor (CKD). Parameters for cement production GHG emissions are presented in Table 1-9.

c. Uncertainties

The activity data uncertainty was given as 25% from the CCIIDI for the years 2017 to 2020,and was applied for the whole time series. Default emission factor uncertainty of zero (0%) obtained from 2006 IPCC Guidelines was used.

Time series consistency and Category-specific Recalculations

In the both the SNC and TNC, GHG emissions from cement were calculated using tier 1 methodology. Emissions calculations were performed for the years 1990 to 2019. There was no available activity data from the SNC for comparison.

d. Category-specific QA/QC and Verification

QA/QC Activity	**Comment**
Compare emissions estimated using different tiers.	Tier one was used due to the unavailability of clinker fraction data and no comparisons were done.
Compare aggregated national emission factors with the IPCC default factors in order to determine if the national factor is reasonable relative to the IPCC default.	National emission factors are not yet developed
Review inconsistencies between sites to establish whether they reflect errors, different measurement techniques, or result from real differences in emissions, operational conditions or technology.	Not carried out during the current inventory cycle.

e. Category-specific Planned Improvements

Constraint/gap	Planned improvement
Cement data was missing for the years 1991, 1992 and 2001. Cement production data for 2001 was interpolated while that for 1990 to 1992 was extrapolated. Clinker production data was unavailable from 1990 to 2016	Collect clinker data for the years from 1990 to 2017 and calculate GHG emissions for 1990 to 2019 using tier 2.
Tier 2 methodology could on be applied for the years 2017 to 2019 due to clinker data availability.	Calculate GHG for the whole time series using tier 2.
Default Cement Kiln Dust (CKD) value used from IPCC Guidelines	Collect data on CKD from the individual plants and calculate the CKD value for the country.

1.10.1.2 2 A 2 Lime Production

This section covers CO_2 emissions from lime production. The two types of lime produced from Ethiopia are high calcium and dolomitic lime. Activity data on lime production was obtained from the CSA (CSA, 2021). It was, therefore, assumed that the lime production data from CSA included both marketed and non-marketed lime, since the data was obtained from census of industrial manufacturers.

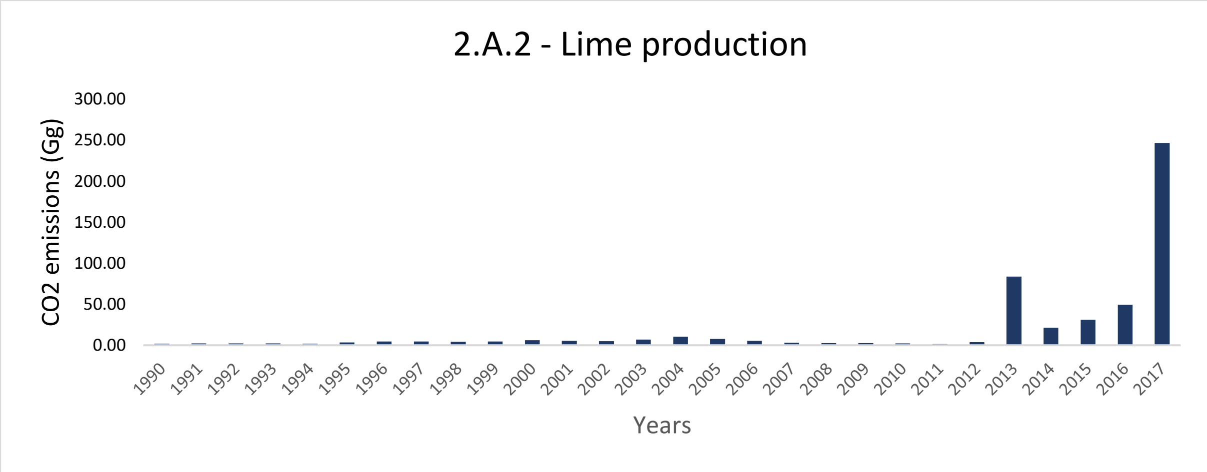

Figure 1-6: CO_2 emissions from Lime production

CO_2 emissions from Lime production were fluctuating below 11Gg CO_2eq for the period 1990 to 2012 and there was a sharp increase in 2013 of about 87% from the 2004 peak of 10.26Gg CO_2eq to around 83.69Gg CO_2eq. A sharp decline in the emission levels was experienced in 2014 followed by a steady increase up to 2016. In 2017 there was a sharp increase to a triple digit figure of 246.17Gg CO_2eq thus about 99% change from the 1990 level.

a. Methodological issues

The Tier 1 methodology was used to calculate CO_2 emissions from lime production. The decision tree for estimation of CO_2 emissions from lime production in Figure 2.2 in section 2.3.1.1 in Chapter 2 of Volume 3 of the 2006 IPCC guidelines was applied. The activity data is presented in Table 1-11. The IPCC default emission factors on lime production Activity data was applied on high calcium lime and hydraulic lime.

b. Activity data

Table 1-11 below presents data on high calcium lime and hydraulic lime production in tonnes from 1990 to 2017.

Table 1-11: Lime production data

Type of Lime Produced	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
High calcium lime	1249.016	1357.626	1475.680	1475.680	1091.522	1978.935	2890.007	2940.132	2654.219	2772.113
Hydraulic lime	1865.736	2027.974	2204.320	2204.320	1630.478	2956.065	4316.993	4391.868	3964.781	4140.887

Type of Lime Produced	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
High calcium lime	3,718.47	3,424.14	3,129.81	4,223.33	6,287.28	4,751.85	7,098.15	1,788.86	1,631.27	1,535.43
Hydraulic lime	5,554.53	5,114.86	4,675.20	6,308.67	9,391.72	7,098.15	4,876.46	2,672.14	2,436.73	2,293.57

Type of Lime Produced	2010	2011	2012	2013	2014	2015	2016	2017
High calcium lime	1,304.85	994.88	2,254.02	51,299.93	7,122.96	9,331.27	21,417.01	304,709.07
Hydraulic lime	1,949.15	1,486.12	3,366.98	76,630.07	27,119.00	40,615.00	56,446.00	29,888.00

Source; (CSA, 2021)

The default emission factors from the IPCC Software Version 2.691 taken from table 2.4 in Section 2.3.1.2 in Chapter 2 of the 2006 IPCC Guidelines Volume 3 (Table 1-12).

Table 1-12: Emission factor for lime production

Emission factor	Source	Comment
0.75 (High calcium lime)	IPCC Default, T1	Default emission factor was applied
0.59 (hydraulic lime)	IPCC Default, T1	

c. Uncertainties

The activity data uncertainty of 1% was obtained from the CCIIDI. IPCC default emissions factor uncertainties value of 0% were used.

d. Time series consistency and category-specific Recalculations

Recalculations were performed for the whole time series. However, GHG emissions for years in between the reporting year were not available. Hence, the comparisons were only done in the reporting years as presented in the table (Table 1-13) below.

Table 1-13: Lime emissions recalculations

	Reported in the INC	Reported in the SNC	Recalculated in the TNC		TNC	% Difference (TNC-INC)	% Difference TNC-SNC)
	1994	2013	1994	2013	2017		
Lime production	**310**	1,757.	**167.81**	3127.83	4768.95	**-45.87%**	**78.02%**

The differences were largely attributed to improvement in the source categories covered in the latest inventory, compared to the previous ones.

e. Category-specific QA/QC and Verification

Lime production data from CSA was compared with that from CCIIDI for the years in which both sources had data.

QA/QC Activity	Comment
Compare between emissions estimated following the Tier 2 approach based on lime production and Tier 3 approach based on carbonate input.	Tier one was used. Available data was not appropriate for tier 2 or 3, hence no comparison was made.
Confirm the correct definitions of the different types of lime produced in the country.	The definitions from CSA were used.
Consider industries that may produce non-marketed lime to ensure that these data have been included in the activity data for the inventory	Only data from CSA was used.

f. Category-specific Planned Improvements

Constraint/gap	Planned improvement
Although Lime production is a key category, the GHG emissions from lime production were calculated using tier 1.	Collect plant specific data on lime production and calculate GHG emission using tier 2 or higher since lime production is a key category.
Data on lime production was not complete in order to determine whether other types of lime, besides high calcium and hydraulic, were being produced	Confirm the correct definitions of the different types of lime produced in the country. Consider industries that may produce non-marketed lime to ensure that these data have been included in the activity data for the inventory

1.10.1.3 2 A 3 Glass Production

According to the data provided by CSA, flat glass and glass bottles are produced in Ethiopia. The cullet ratio used in glass production was 0.4.

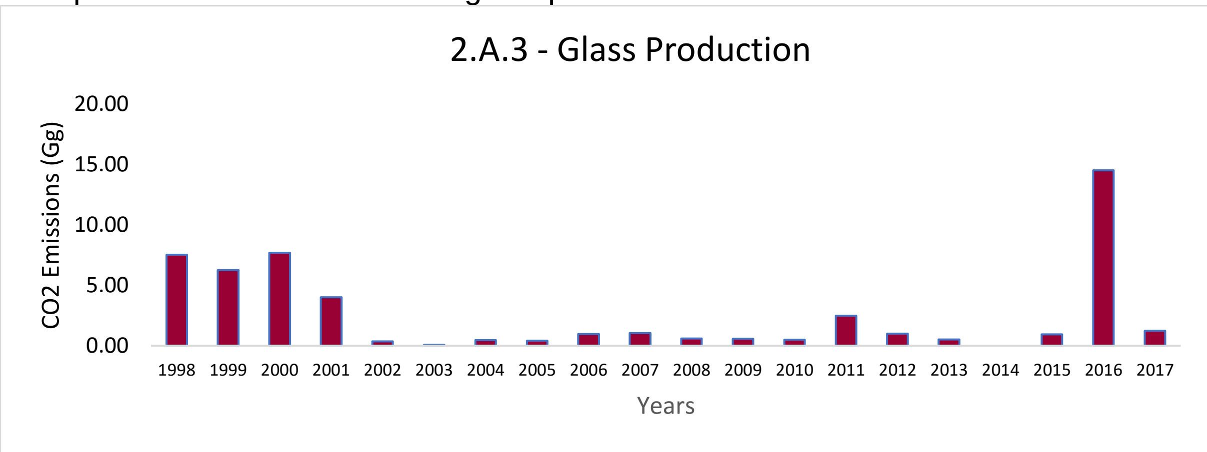

Figure 1-7: CO_2 emissions from glass production

The CO_2 emissions in glass production from 1998 up to 2001 were hovering around 7Gg CO_2eq. There was a sharp decline in CO_2 emissions in the period from 2001 up to 2015 with intermittent spikes in between followed by a sudden increase in 2016 of about 48% from the 1998 level. In 2017, a sharp decline to about 1.24Gg CO_2eq was experienced in the emissions.

a. Methodological issues

Tier 1 methodology was used following Figure 2.3 decision tree in section 2.4.1.1 of Volume3 Chapter 2 in the 2006 IPCC Guidelines. Tier 1 applies a default emission factor and cullet ratio to national-level glass production statistics using Equation 2.10.

b. Activity data

Glass and glass bottles activity data was combined and GHG emissions obtained by computing in the IPCC Software Version 2.691. Table 1-14 shows data for glass production from 1998 to 2019. Details of bottles and glass produced, as well as the conversions done are presented in **Error! Reference source not found.** and Annex B. The default emission factor of 0.21kg CO_2/tonne of glass produced was obtained from the 2006 IPCC Guidelines section 2.4.1.2 of Chapter 2, Volume 3. A cullet ratio of 0.4 was used.

Table 1-14: Glass production data

Year	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Production (mt)	59928.38	49837.71	61013.96	31908.83	2803.7	600.34	3778.03	3329.65	7741.82	8467.12	4717.67
Year	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Production (mt)	4628.99	3891.3	19680	7988	4133		7454.92	115383	9822		0

Source; (CSA, 2021)

c. Uncertainties

The uncertainty of 5% was obtained from default. A cullet ratio of 0.4 was used.

Time series consistency and Category-specific Recalculations

Recalculations were performed for 1998 to 2019. There was no data from the SNC to compare with for recalculations. Emissions figures were only available for reporting years.

d. Category-specific QA/QC and Verification

QA/QC Activity	Comment
Emissions estimated using a Tier 3 approach could be compared with the results using a Tier 2 approach to see if the results are of a similar order of magnitude.	Not performed since tier 1 method was used.
Consideration of the cullet ratio	Default cullet ratio of 0.4 was used.

e. Category-specific Planned Improvements

Constraint/gap	Planned improvement
A default cullet ratio of 0.4 was used	Determine the national average cullet ratio and use it for calculating GHGs from glass production in Ethiopia.

1.10.1.4 2 A 4 Other Process Uses of Carbonates

GHG emissions reported under this category were from production of ceramics 2A4.a. The GHG emissions covered the production of clay bricks, floor and wall tiles.

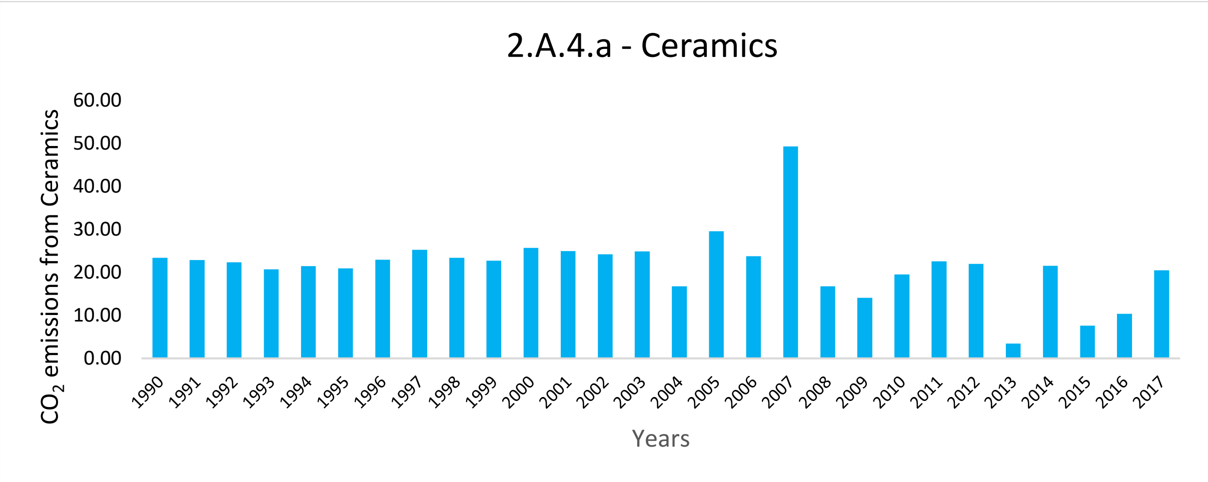

Figure 1-8: CO_2 emissions from Ceramics

The graph depicts a declining trend in CO_2 emissions since 1990 up to 2017 with a spike in 2007. The decline of CO_2 emissions from 23.34Gg CO_2eq in 1990 to 20.50Gg CO_2eq in 2017 represents about 12% increment.

1.10.1.5 2 A 4 a Ceramics

The section presents CO_2 emissions from the production of bricks, as well as wall and floor tiles were reported.

a. Methodological issues

The Tier 1 methodology was used based on Equation 2.14 in section 2.5.1.1 of Volume3 Chapter 2 of the 2006 IPCC Guidelines.

b. Activity data

Activity data under ceramics was from cement floor tiles and clay bricks from 1998 to 2017, and was obtained from the CSA (Table 1-15). Data for 2001 were missing and the gap was filled by trend interpolation. Activity data for cement floor tiles from the CSA were presented in square metres (m^2). The data was converted to density by multiplying by 20kg, which is the average density of a SQ.M of ceramic tiles[1]. The total was converted to tonnes for entry into the IPCC Software Version 2.691 entry by dividing by 1000 and multiplied by 1.1 (an IPCC default figure for losses).

The units used for clay bricks data were 1000 pieces (PCS). The data was multiplied by 1000 to get the actual number of PCS of bricks, which was then converted to density through multiplying by1.88, which is the average weight (in kgs) of standard clay bricks[2]. The total was converted to tonnes for entry into the IPCC Inventory software through dividing by 1000 and then multiplied by 1.1 to cover for loses (an IPCC default for loses).

Table 1-15: Ceramics data in tonnes

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Cement floor tiles	8,103.22	7,494.34	12,124.35	8,501.99	4,879.62	8,710.15	5,405.31	10,689.10	20,966.24	10,247.14
Clay bricks	40,923.65	40,139.88	41,674.34	43,699.94	45,725.55	43,347.35	29,642.71	51,255.38	28,730.72	92,971.08

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Cement floor tiles	6,319.65	2,477.55	4,380.02	9,102.08	17,084.45	4,182.46	19,728.76	13,719.88	127,088.21	24,092.93
Clay bricks	28,763.81	27,063.92	36,489.86	38,067.74	28,902.37	2,979.99	25,277.16	2,177.60	8,942.03	18,858.09

Source; (CSA, 2021)

c. Emission factor for tiles and clay bricks

Emission factor	Source	Comment
0.47732	IPCC Default	Default emission factor for dolomite was applied

d. Uncertainties

Default figures in the IPCC software were used, that is +/-5% for activity data and 0 for the EFs.

e. Time series consistency and Category-specific Recalculations

Emissions from ceramics were not estimated in earlier inventories, hence no recalculations were performed.

f. Category-specific QA/QC and Verification

[1]Source; https://www.tiles.org.uk/wp-content/uploads/2018/07/TTA-Tiling-Guide-Brief-guidance-on-the-use-of-adhesives.pdf).

[2]Source; https://www.ijert.org/research/laboratory-investigation-of-locally-produced-clay-brick-quality-and-suitability-for-load-bearing-element-in-jimma-area-ethiopia-IJERTV6IS050526.pdf

QA/QC Activity	Comment
Emission estimates derived from any Tier to be compared with the other Tiers	Only tier 1 was used
Compare plant specific information with industry association statistics. Examine trends in activity data over time to see if there may be large fluctuations year to year, as there may be large year to year fluctuations in these statistics.	Data were obtained from CSA, plant specific data were not available.

g. Category-specific Planned Improvements

Constraint/gap	Planned improvement
The category specific QA/Qc plan was not in place	Develop and implement a category specific QA/QC plan

1.10.1.6 2 A 4 b Other Uses of Soda Ash

Emissions from the use of soda ash besides that in other processes were not reported. The data on the specific processes and quantities were not available. It was, therefore assumed that data reported as raw material use by the CSA was used in other processes.

1.10.2 2 B Chemical Industry

This section covers GHG emissions from soda ash production. The following activities do not occur in Ethiopia:

- B 1 Ammonia Production
- B 2 Nitric Acid Production
- B 3 Adipic Acid Production
- B 4 Caprolactam, Glyoxal and Glyoxylic Acid Production
- 2 B 5 Carbide Production
- 2 B 6 Titanium Dioxide Production
- 2 B 8 Petrochemical and Carbon Black Production
- 2 B 8 a Methanol Methanol production
- 2 B 8 b Ethylene Ethylene production
- 2 B 8 c Ethylene Dichloride and Vinyl Chloride Monomer production
- 2 B 8 d Ethylene Oxide Ethylene oxide production.
- 2 B 8 e Acrylonitrile Acrylonitrile production
- 2 B 8 Petrochemical and Carbon Black Production
- 2 B 8 a Methanol Methanol production
- 2 B 8 b Ethylene Ethylene production
- 2 B 8 c Ethylene Dichloride and Vinyl Chloride Monomer production
- 2 B 8 d Ethylene Oxide Ethylene oxide production.
- 2 B 8 e Acrylonitrile Acrylonitrile production
- 2 B 9 Fluorochemical Production 2E HFCs,
- B 10 Other

1.10.2.1 2 B 7 Soda Ash Production

In Ethiopia Soda ash (sodium carbonate, Na_2CO_3) is produced through natural processes from sodium sesquicarbonate (trona).

a. Methodological issues

The Tier 1 methodology was used, based on Equation 2.14 in section 2.5.1.1 of Volume3 Chapter 2 the 2006 IPCC Guidelines. Data was only available at National level, and no plant specific data was available.

b. Activity data

Data for the production of soda ash provided by the CCIIDI only covered the years 2016 to 2019 (Table *1-16*).

Table 1-16: Soda Ash Production

Period (EFY)	Year	Production I capacity
2008	2016	4800
2009	2017	5850
2010	2018	6503
2011	2019	2933
2012	2020	1531

Source: (CCIIDI, 2021)

c. Emission for soda ash production

CO_2 emissions from soda ash production were only reported for 2016 to 2019, since activity data was only available for these years. The emissions ranged from 0.28Gg in 2019 to the highest of 0.81Gg produced in 2017.

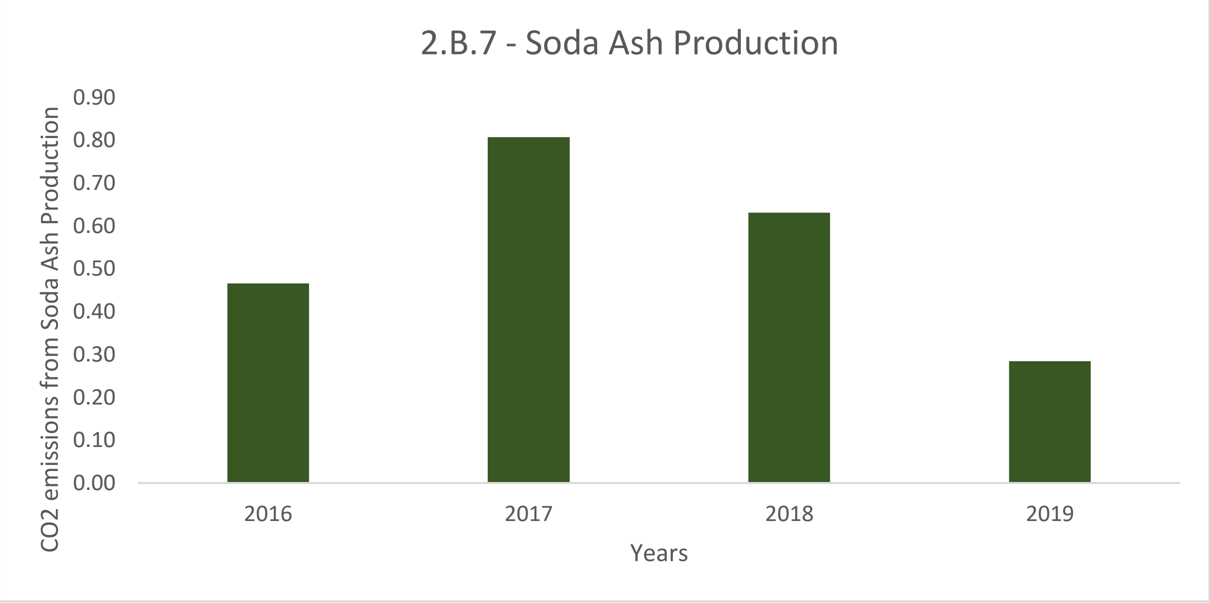

Figure 1-9: CO_2 emissions from soda ash production

Generally the CO_2 emissions from Soda Ash Production declined over the period of 2016 to 2019.Despite the spike in 2017, the 2019 figure of 0.28Gg CO_2eq represents about 40% decline in emissions from 2016 level.

d. Uncertainties

Default uncertainties of +/-5% for activity data and 0% for EFs were used**.**

e. Time series consistency Category-specific Recalculations

GHG emissions from the production of Soda ash were reported since the INC. However, for the TNC inventory cycle, the activity was only available for the years 2016 to 2020. Tier 1 methodology was use in the INC, SNC and TNC.

f. Category-specific QA/QC and Verification

No category specific QA/QC activities were performed. There were no other sources to compare with for the years where CCIIDI provided data.

g. Category-specific Planned Improvements

Activity data for soda ash production was only available for the years 2016 to 2019, although the production of soda ash has been happening in Ethiopia since 1990. There is need to collect soda ash production data for the whole time series and calculate GHG emissions from soda ash production.

1.10.2.2 2 B 8 f Carbon Black production

Activity data on production of carbon black was not available, hence GHG emissions from this category were not estimated.

1.10.3 Metal Industry 2C

1.10.3.1 2 C 1 Iron and Steel Production

CO_2 is the predominant gas emitted from the production of steel. Emissions reported from metal industry were from the secondary production of steel in electric arc furnaces. There was no primary production of metals in Ethiopia for the reporting period. Figure 1-10 presents the CO_2 emissions from steel production for the entire time series.

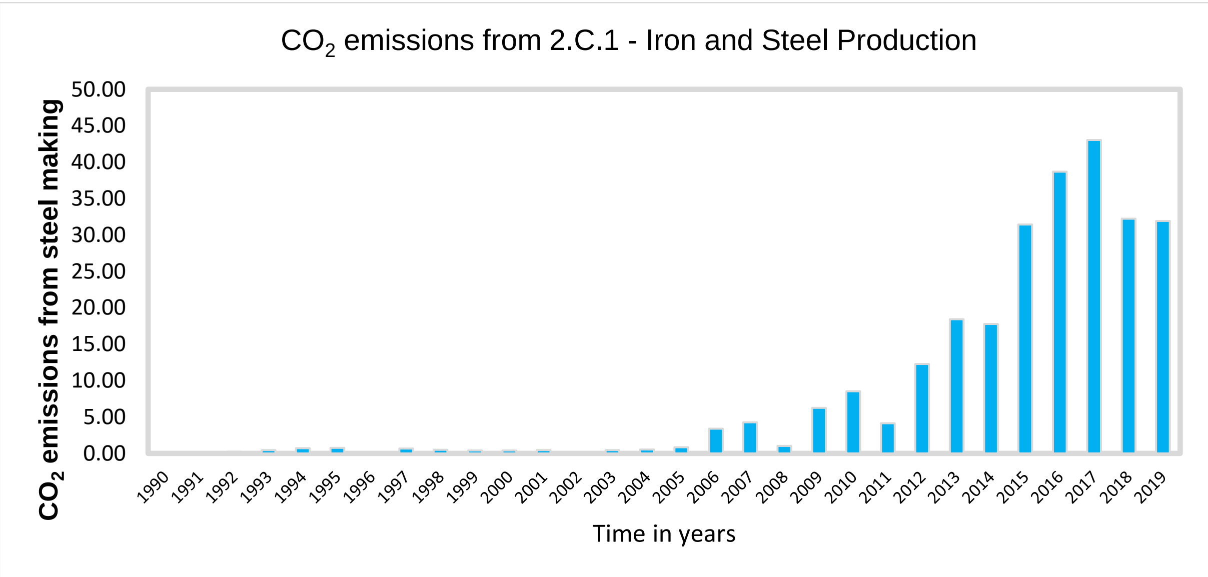

Figure 1-10: CO_2 emissions from iron and steel.

Since 1993 the CO_2 Emissions were almost constant and started to increase sharply in 2005 reaching a peak in 2017, dropping suddenly in 2019 to 2018. The change of emissions from the 1993 level to the 2019 level represents 99%.

a. Methodological issues

Tier 1 methodology was used in accordance with the IPCC decision tree in Figure 4.7 for CO_2 emissions in section 4.2.2.2 of Volume 3 of the 2006 IPCC Guidelines (IPCC, 2006).

b. Activity data

Table 1-17 presents quantities of rebar (in metric tonnes) produced from 1990 to 2019. However, there was no data of different processes of making rebars from different companies. Hence, the main assumption is that all rebars were made through electrical furnace process. The data was obtained from MIDI- Environment, Safety and Energy Directorate (ESED). Data for 2001 were missing and the gap was filled by trend interpolation. The quantities of rebar produced for the whole time series are presented in Table 1-17.

Table 1-17: Steel production data

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
Rebar (mt)	791.294	1515.888	2904	5518	8920	9449	1159	8512	6203	5357
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Rebar (mt)	5,078.00	5,713.62	1,082.88	5,487.92	6,570.80	10,610.50	42,242.71	53,326.75	12,596.84	78,290.62
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Rebar (mt)	106,599.19	51,995.49	153,484.78	230,363.21	222,108.92	393,173.67	483,752.64	537,894.42	402,717.19	398,794.20

Source: (MIDI-ESED, 2021)

c. Emission factor for steel

The IPCC default EF for the electric Arc Furnace (EAF) for steel making of 0.08 tonne CO_2 per tonne of steel produced was used, taken from Table 4.1 in section 4.2.2.3 of the 2006 IPCC Guidelines Volume 3.

d. Uncertainties

The activity data default figure of 2% was provided by MIDI. The IPCC default uncertainty for EF was 0% and was obtained from IPPC software.

e. Time series consistency Category-specific Recalculations

Recalculations were performed for the whole time series and the difference between the recalculated figure and the one reported in the SNC was -97.89%. However, data used in the SNC was not available, hence it was not possible to identify the source of the error.

f. Category-specific QA/QC and Verification

QA/QC Activity	**Comment**

Review of emission factors and carbon contents. Compare aggregated national emission factors and carbon contents with the IPCC default factors carbon contents in order to determine if the national value is reasonable relative to the IPCC default. Explanation on differences between national default values to be explained and documented, particularly if they are representative of different circumstances.	Default data was used and no comparison were made.
Review of inconsistencies between sites to establish whether they reflect errors, different measurement techniques, or result from real differences in emissions, operational conditions or technology.	Activity data was obtained from the CSA and MIDI.
To include key industrial trade organisations associated with iron and steel production in a review process. This process should begin early in the inventory development process to provide input to the development and review of methods and data acquisition Involving third party reviews for this source category, particularly related to initial data collection, measurement work, transcription, calculation and documentation.	MIDI already involved and plans underway for MIDI to be responsible for collecting all data on steel production.

g. Category-specific Planned Improvements

Constraint/gap	Planned improvement
It was assumed that all metals were made from the electric arc furnace process	Conduct survey on steel making companies to establish the quantities of steel produced from the different processes in Ethiopia.
	Develop and implement a system for collection of activity data by MIDI

Primary production of metals was not occurring in Ethiopia, hence the following activities were reported as NO;

i. **C 2 Ferroalloys production**
ii. **C 3 Aluminum production**
iii. **C 4 Magnesium production**
iv. **C 5 Lead production**
v. **2 C 6 Zinc production**
vi. **2 C 7 Other (please specify)**

1.10.4 Non-Energy Products from Fuels and Solvent Use-2 D

This section presents CO_2 emissions from the use of oil products and coal-derived oils primarily intended for purposes other than combustion. The data was obtained from the Customs department and covered the years from 2007 to 2019. The emissions from 2D had a lot of inconsistencies owing to data gaps.

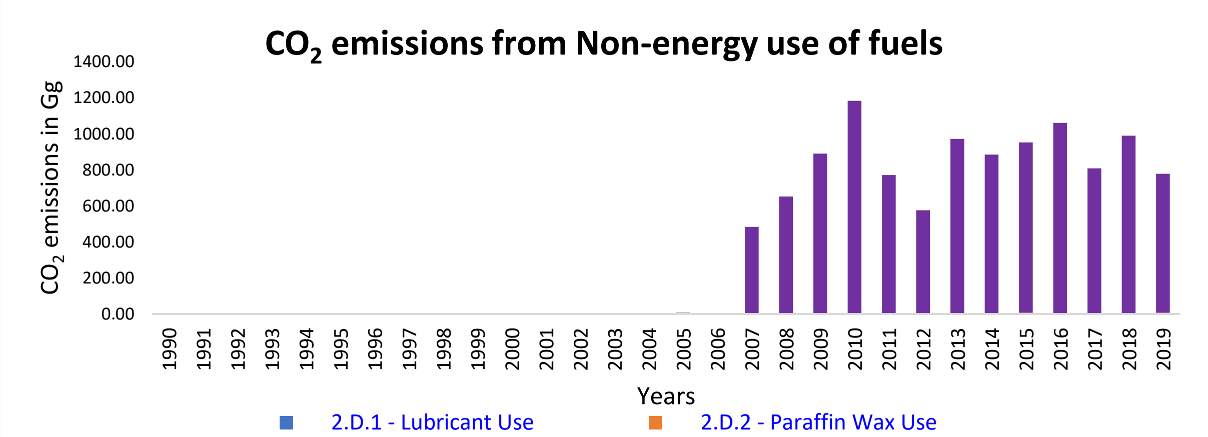

Figure 1-11: CO_2 emissions from NEU of fuels

The CO_2 emissions from none-energy use of fuels increased from 2007 to 2010.From the period of 2011 to 2012 the emissions were declining, however an upward trend was noticed from 2013 onwards.

1.10.4.1 2 D 1 Lubricant Use

Lubricating oils, heat transfer oils, cutting oils and greases.

a. Methodological issues

Tier 1 methodology was used to calculate CO_2 emissions, following Equation 5.2, in accordance with Figure 5.2 decision tree for estimation of CO_2 emissions from non-energy uses of lubricants, section 5.2.2.1 of Volume 3 Chapter 5 of the 2006 IPCC guidelines. The default tier methodology was used.

b. Activity data

Table *1-18* presents data of Lubricant use from 2007 to 2019. Data was obtained from imports. Activity Data for Preparations for lubricating materials, with <70% petroleum oil was combined with Other lubricating preparations, with <70% petroleum oil, However, 2008 activity data for Other lubricating preparations, with <70% petroleum oil was missing.

Table 1-18: Lubricant use data

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Preparations for lubricating materials, with <70% petroleum oil (TJ)	5.72	6.74	5.70	13.43	5.15	10.68	6.56	6.47	3.70	3.36	3.71	4.65	3.14
Other lubricating preparations, with <70% petroleum oil (TJ)	5.15	No data	15.00	9.22	2.81	1.08	2.98	2.34	5.49	4.89	5.17	5.35	4.12

Source; (Customs, 2021)

c. Emission for Lubricant use Emissions Factors

Emission factor	Value	Source	Comment
ODU Factor	0.2	2006 IPCC GLs Default	Default emission factor was applied
Net calorific value for wax (TJ/Gg)	40.3	2006 IPCC GLs Default Volume 2, Table 1.2 Chapter 1	

d. Uncertainties

Activity data uncertainties were 10% while that for EFs was 0% obtained from the 2006 IPCC Guidelines (IPCC, 2006) were used.

e. Time series consistency

Recalculations were not performed since the emissions from 2D were not estimated in the SNC

f. Category-specific QA/QC and Verification

QA/QC Activity	Comment
Check the consistency of the total annual consumption figure with the production, import and export data.	Comparison with data from petrochemicals-CCIIDI

g. Category-specific Planned Improvements

Constraint/gap	Planned improvement
Data was not complete for the whole time series and products. Data on lubricants were not complete	Collect all data, including lubricants, and calculate GHG emissions from non-energy use of fuels, considering that the category is key.

1.10.4.2 2 D 2 Paraffin Wax

The CO_2 emissions from the use of all waxes uses, except for energy purposes, were reported under this section. The waxes included paraffin and other waxes with less than 70% wax content. Other Oil-derived waxes such as petroleum jelly, paraffin waxes and other waxes were also included.

a. Methodological issues

The Tier 1 methodology was used, following Figure 5.3 decision tree for estimation of CO2 emissions from non-energy uses of paraffin waxes, in section 5.3.2.1 of Volume 3 Chapter 5 of the 2006 IPCC guidelines (IPCC, 2006). CO2 emissions were calculated according to Equation 5.4 with aggregated default data for the limited parameters available.

b. Activity data

Table 1-19 presents Activity data from paraffin wax use from 2007 to 2019. The data was obtained from industry and customs. Vaseline activity data presented was from 2011 to 2017.

Table 1-19: Paraffin Wax use

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Paraffin wax, containing <0.75% oil	77.15	79.35	69.26	95.00	124.82	138.22	160.72	177.36	244.45	193.22	197.42	182.35	260.64
Vaseline					0.0020	0.0023	0.0003	0.0079	0.0012	0.0010	0.1468		
Petroleum jelly Imports	157.32	123.65	119.31	76.62	123.67	106.89	134.41	106.20	196.77	91.35	153.72	114.28	187.13
Other paraffin wax... and similar products, nes	41.39	21.68	39.12	35.18	48.71	37.88	56.28	92.34	61.61	82.30	29.54	50.85	103.26

c. Paraffin wax Emissions Factors

The default ODU factor of 0.2 was obtained from the 2006 IPCC Guidelines. The calorific value used was 40.2 TJ/Gg, taken from Table 1.3 in Chapter of the 2006 IPCC Guidelines Volume 2.

d. Uncertainties

Default uncertainties of 10% from the IPCC Software Version 2.691 were used.

e. Time series consistency

Category-specific Recalculations

Recalculations were not performed since the emissions from 2D2 were not estimated in the SNC.

f. Category-specific QA/QC and Verification

g. Category-specific Planned Improvements

Constraint/gap	Planned improvement
Data used was from imports since that provided by Petrochemical Department were not complete	Collect production and import data for paraffin wax uses

1.10.4.3 2 D 3 Solvent Use

NMVOC emissions from solvent use, for example in paint application, degreasing and dry cleaning were not reported since the activity data was not available.

1.10.4.4 2 D 4 other (please specify)

This section covers the NMVOC emissions from asphalt production and use. Asphalt is applied on roads and as roofing material.

a. Methodological issues

Calculations were done in the IPCC default methodology provided in Section 5.4 of the 2006 IPCC Guidelines (IPCC, 2006).

b. Activity data

Table 1-20 presents Activity data on various non-energy fuels used. Bituminous or oil shale and tar sands, Bitumen and asphalt; natural asphaltites and asphaltic rocks and Bituminous mixtures based on natural asphalt, bitumen.

Table 1-20: Other non-energy fuels

	2007	2008	2009	2010	2011	2012
Bituminous or oil shale and tar sands	214.89	523.25	806.39	1054.85	1508.38	140.65
Bitumen and asphalt; natural asphaltites and asphaltic rocks	1921.72	2720.95	2602.65	3362.38	1913.44	2285.52
Bituminous mixtures based on natural asphalt, bitumen.	257.36	1365.29	1019.03	1475.70	409.89	426.83

	2013	2014	2015	2016	2017	2018	2019
Bituminous or oil shale and tar sands	98.26	70.16	53.71	197.51	258.18	2.82	200.46
Bitumen and asphalt; natural asphaltites and asphaltic rocks	3629.06	3725.00	2666.04	2918.23	2470.12	2858.53	2069.63
Bituminous mixtures based on natural asphalt, bitumen	1104.32	596.43	2004.16	2160.35	1286.71	2058.86	1591.70

Source: (CSA, 2021)

c. Other non-energy fuels emissions Factors

The default ODU factor of 0.2 was obtained from the 2006 IPCC default software.

d. Uncertainties

Default uncertainties of 10% for activity data and 05 for EFs from the IPCC Software Version 2.691 was used

e. Time series consistency

The IPCC default methodology was used for the whole time series

Category-specific Recalculations

Recalculations were not performed since the emissions from 2D were not estimated in the SNC.

f. Category-specific QA/QC and Verification

QA/QC Activity	Comment
Check the consistency of the total annual consumption figure with the production, import and export data.	Production figures were not available and imports figures were used.

g. Category-specific Planned Improvements

Constraint/gap	Planned improvement
Activity data was not available for the whole time series, covering only years from 2007 to 2013	Collect activity data from 1990 to 2006 and calculate GHG emissions for the whole time series.

1.10.5 2 E Electronics Industry

Emissions from the Electronics industry (2E) were not occurring in Ethiopia. The only activities that occur pertain to the assembly of the components. Hence, the following were reported as NO:

- **2 E 1 Integrated Circuit or Semiconductor**
- **2 E 2 TFT Flat Panel Display**
- **2 E 3 Photovoltaics**
- **2 E 4 Heat Transfer Fluid**
- **2 E 5 Other (please specify)**
- **2E6 other halogenated gases**

1.10.6 2 F Product Uses as Substitutes for Ozone Depleting Substances

The most commonly used ODS alternatives in Ethiopia include HFC-134a, and HFC-245fa. Other HFCs are mostly used as components of blends used mainly in the refrigeration and air conditioning, foam and aerosol sectors. The three dominant HFC blends currently used are R-404A, R-410A and R-407C. In Ethiopia the dominant task is maintenance where gas filling is the common practice in air condition and refrigeration sector. The main substance used in refrigeration sector is HFC-134A widely used for domestic refrigeration. Furthermore, R-404A, R-407C and few amount of R-12, R-13b is used in this sector. In Ethiopia the major refrigerator gas used by technician to maintain refrigerators is HFC-134a. Other blends and R-717 are also used specially in small and medium industries. Basically the air condition and refrigerator sector consume such gases during maintenance and other technical processes.

The aerosol sector is also found in a better stage for its use of HAPs which are considered the best replacement of the ODS aerosols.

The three dominant HFC blends currently used are R-404A, R-410A and R-407C.

1.10.6.1 2 F 1 Refrigeration and Air Conditioning

GHG emissions from both mobile and stationary air conditioning were not estimated owing to data constraints. Quantities of manufactured regenerators were obtained from MIDI while the imported refrigerators quantities were obtained from the Customs department. However, the details on the gases in the new equipment were not provided. The report on the survey conducted by the Ozone secretariat provided quantities of ODS substitutes in use, without giving further details. The data on the six sub-applications (2006 IPCC Guidelines Section 7.5.1) was not provided. The required applications are:

a Domestic refrigeration,
b Commercial refrigeration including different types of equipment, from vending machines to centralised refrigeration systems in supermarkets,
c Industrial processes including chillers, cold storage, and industrial heat pumps used in the food, petrochemical and other industries,
d Transport refrigeration including equipment and systems used in refrigerated trucks, containers, reefers, and wagons,
e Stationary air conditioning including air-to-air systems, heat pumps, and chillers for building and residential applications,
f Mobile air-conditioning systems used in passenger cars, truck cabins, buses, and trains.

The available activity data could not be used for 2006 IPCC Approach A or B.

The survey reports states that maintenance of mobile air conditioning system and industrial chillers is indeed occurring and that typical gases used in this industry are R-717, R-404A, R-407C and other unclassified gases such as R-22, R-502, R-503,R-393,R-394. The report further indicates that domestic air conditioning uses R-22 and it was the development of this substance that facilitated the development of small scale efficient air conditioning units suitable for residential applications while room air conditioners use small air conditioning units suitable for comfort cooling of a single room or enclosed small commercial space. The calculation of GHG emissions from the use of ODS substitutes in refrigeration and air conditioning will be addressed through the planned improvement in the TNC.

1.10.6.2 2 F 2 Foam Blowing Agents

In the foam sector HFO-1234ze, HFO-1233zd and HFC-245fa are extensively used in Ethiopia. The processes and applications for which these various HFCs are being used include insulation boards and panels, pipe sections, sprayed systems and component gap filling foams. For open-cell foams, such as integral skin products for automotive steering wheels and facias, emissions of HFCs used as blowing agents are likely to occur during the manufacturing process.

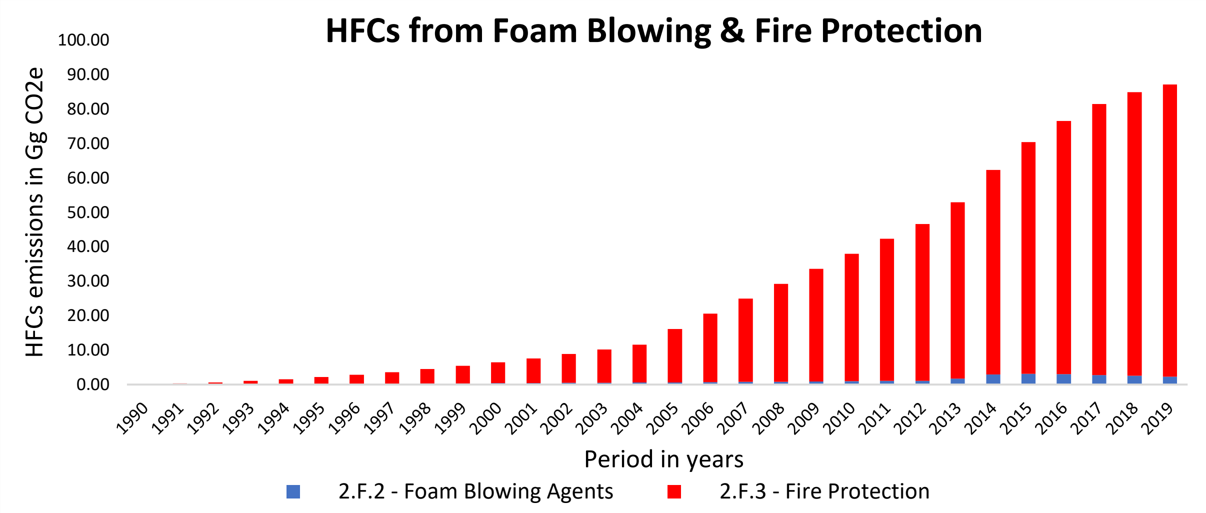

Figure 1-12: HFC emissions from foam blowing and fire protection

HFC Emissions were on a steady increase trend from 1990 up to 2019. The change in emissions from 1990 levels of 0.10Gg CO_2eq to 84.7Gg CO_2eq in 2019 represents about 99% increase.

a. Methodological issues

Tier methodology was used and calculations performed in the IPCC Software Version 2.691. Equation 7.8 from Section 7.4.2.1 from the 2006 IPCC Guidelines Volume 3 Chapter 7 was employed.

a. Activity data and emission factor for foam blowing

Activity data was obtained from the Survey on ODS conducted by the Ozone Secretariat in 2018 (Table 1-21).

Table 1-21: Activity data and emission factors for foam blowing

Subsector/ application	**Alternatives**									
			2012	**2013**	**2014**	**2015**		**First year losses**	Annual loss	**Lifetime (years)**
Rigid PU	HFO-	C_3H_2Cl	19.5	20.0	45.2	56.9		10	4.5	
Spray	HFC-245fa	$C_3H_3F_5$	3.32	6.65	12.9	13.23		15	1.5	50

Source; (Secretariat, 2018)

The default emission factors of 15 in the first and 1.5% in the subsequent years was used, obtained from the 2006 IPCC Guidelines.

b. Uncertainties

Default uncertainties in the IPCC software of 0% for both activity data and emissions factor were used.

c. Time series consistency

Recalculations were not performed since these were not reported in the SNC**.**

d. Category-specific QA/QC and Verification

e. Category-specific Planned Improvements

Constraint/gap	Planned improvement
Data obtained from Ozone Secretariat only covered the years 2012 to 2015	Conduct survey to collect data covering the years 1990 to current and calculate GHG emissions for the whole time series.

1.10.6.3 2 F 3 Fire Protection

This section presents GHG emissions from the use of ODS substitutes in fire suppression. The data obtained from the Ozone secretariat covered the use of R-744 (CO_2).

a. Methodological issues

Tier 1 methodology from the 2006 IPCC Guidelines was used as outlined in Section 7.6.2.1 of Volume 3 Chapter 7 of the 2006 IPCC Guidelines.

b. Activity data

Activity data was obtained from the Ozone Secretariat and is presented in Table 1-22.

Table 1-22: Gases consumed in foam blowing

Application	Alternative	2012	2013	2014	2015
Fire	R-744 (CO_2)	0.12	0.095	0.47	1.04
Extinguisher	Other(hydrant)	1.5	15.99	11.18	8.13

c. Emission factor for fire protection

d. Uncertainties

Default uncertainties in the IPCC software were used

e. Time series consistency

Category-specific Recalculations

Recalculations were not performed since these were not reported in the SNC

f. Category-specific QA/QC and Verification

Conduct general QA/QC procedures in section 7.6.4.1 in Chapter 7 Volume 3 of the IPCC Guidelines	
Conduct expert review of the emissions estimates	

g. Category-specific Planned Improvements

Constraint/gap	Planned improvement
Data obtained from Ozone Secretariat only covered the years 2012 to 2015.	Conduct survey to collect data covering the years 1990 to current and calculate GHG emissions for the whole time series.

1.10.6.4 2 F 4 Aerosols

GHG emissions from the use of hydrocarbon aerosol propellant (HAPs) Was not available, hence emissions from this category were not estimated.

1.10.6.5 2 F 5 Solvents

Activity data on the use of HFCs as solvents was not available, hence these emissions were not estimated.

1.10.7 2 G Electrical Equipment

1.10.7.1 2 G 1 Electrical Equipment

Activity data on electrical equipment used in the transmission and distribution of electricity above 1 kV was not available. SF_6 is used in gas insulated switchgear (GIS), gas circuit breakers (GCB), gas-insulated transformers (GIT), gas-insulated lines (GIL), outdoor gas-insulated instrument transformers, reclosers, switches, ring main units and other equipment.

GHG emissions from the following source categories were not estimated owing to lack of activity data:

- **2G 2 SF_6 and PFCs from Other Product Uses**
- **2G 2a Military Applications include AWACS**
- **2G 2b Accelerators Particle**
- **2G 3 N_2O from Product Uses**

h. Category-specific Planned Improvements

GHG emissions from 2 G were not estimated due to lack of data. There is need to collect activity data on this source category and calculate GHG emissions for the whole time series.

1.10.8 Other product manufacture and use-2H

1.10.8.1 H 1 Pulp and Paper Industry,

The GHG emissions were not estimated due to lack of activity data on pulp production.

1.10.8.2 H 2 Food and Beverages Industry

The GHG emissions reported under this category are NMVOCs from the production of alcohol, beer, bread and wine. Beer and bread are the main contributors to emissions from this source category.

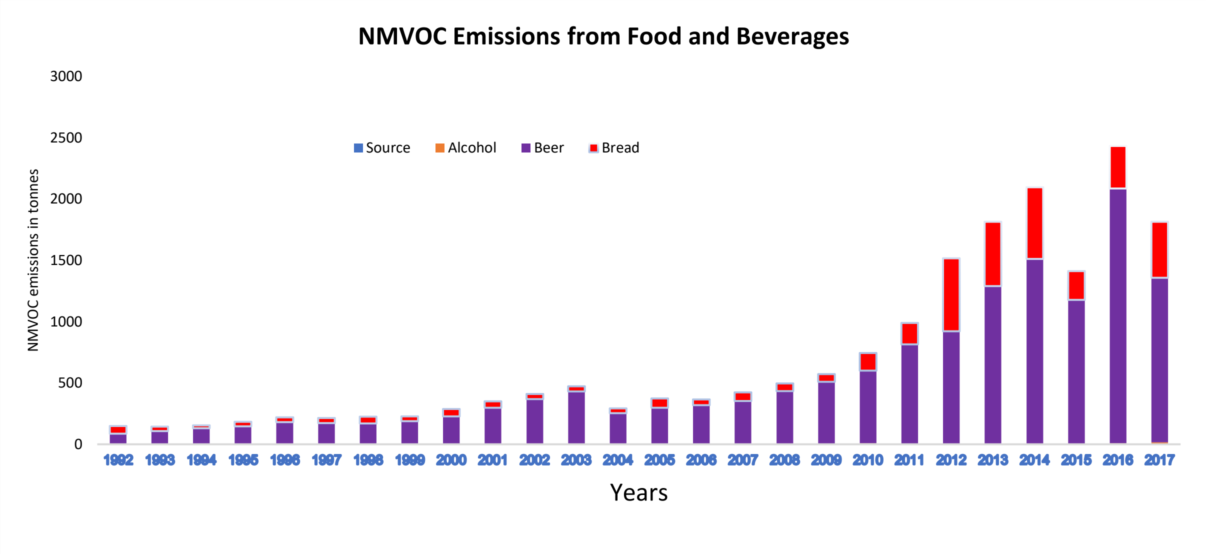

Figure 1-13: NMVOC emissions from food and beverages

The NMVOC emissions from food and beverages have been on a gradual increasing trend since 1992 up to 2011 and thereafter there was a sharp increase up to 2014, surging in 2016.There was a sharp increase in 2016 followed by a decline in 2017. The change of emissions from 148.9Gg CO_2eq in 1992 to 1796.5Gg CO_2eq in 2017 represents about 83% increase in CO_2 emissions.

Methodological issues

The Tier 1 approach for process emissions from the food and beverages industry was applied using annual national total food and beverages production. The Tier 1 emission factors assume an averaged or typical technology and abatement implementation in the country and integrate all different sub-processes in the food and beverages production. The tier method followed Figure 3.1 decision tree for estimation of NMVOCS emissions from the food and beverages industry, in section 3.1 of Volume 2-h-2 of the CORINAIR Guidebook 2019. NMVOCS emissions were calculated according to the following general Equation below:

$$E_{pollutant} = AR_{production} \bullet EF_{pollutant} \ ;$$

Equation 1-1: NMVOCS Food and beverages

This equation is applied at the national level, using annual national total food and beverages production.

Activity data

Table 1-23presents Activity Data for Food and Beverages Industry from 1992 to 2017. The data was obtained from CSA.

Table 1-23: Food and Beverages Industry

Source	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Alcohol	0.59964	0.650294	2.271531	0.365623	2.995991	2.5592	2.338754	2.717947	2.299935	0	3.15316
Beer	86.36651	105.4998	128.1512	146.1561	177.0318	170.2222	167.7703	185.9945	224.4632	0	366.0194
Bread	62.458	37.96	24.72	37.296	40.606	41.544	54.058	38.526	61.53	0	39.958
Wine	9.6064	10.88209	9.059404	11.19793	9.18691	5.58451	4.16488	2.830254	3.70352	0	4.215124

TOTAL	159.0306	154.9921	164.2022	195.0156	229.8207	219.9099	228.3319	230.0687	291.997	0.000	413.346

2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
2.032148	1.137896	1.042269	0	3.189611	2.522117	1.753474	7.855442	2.959066	0.783477	0.166163	4.100906	5.616418	8.915384	16.52087
428.8864	251.8869	295.4806	315.258	350.1811	431.7156	507.723	593.5701	811.148	919.7339	1288.535	1507.372	1170.209	2076.275	1338.915
41.494	39.04	77.154	48.52	68.696	62.51	61.176	141.53	173.86	595.568	523.48	582.78	236.444	345.228	457.61
5.056948	6.336906	10.19511	8.117724	8.352828	7.772336	8.271774	9.059246	10.16604	11.20378	10.13839	10.33731	11.5814	8.890976	15.86589
477.469	298.402	383.872	371.896	430.420	504.520	578.924	752.015	998.133	1527.289	1822.319	2104.590	1423.851	2439.309	1828.912

Source; (CSA, 2021)

f. Emission Factors for food and beverages

Emission factor	Source	Comment
(Tier 1)	Default (CORINAIR)	Default EF from CORINAIR Guidebook 2019.

g. Time series consistency

Category-specific Recalculations. Recalculations were not performed since these were not reported in the SNC

h. Category-specific QA/QC and Verification

Conduct general QA/QC procedures in section 7.6.4.1 in Chapter 7 Volume 3 of the IPCC Guidelines	

1.11 Status of Planned Improvements from SNC

Constraint/gap	Planned improvement	Status
Data for national cement production provided by the CSA was used and not production data from factories or institutions	Collect cement and clinker production from the CCIIDI	Activity data used in the TNC was obtained from the CSA and CCIIDI, covering 2002 to 2019
Activity data on non-energy use of fuels: lubricants, bitumen, asphalt	Collect data on NEUs and calculate emissions	Data on NEUs was collected from CSA, Customs and MIDI.
GHG emissions from refrigeration and air conditioning were not estimated since the data was over-aggregated	Collect HFC data and data on and AC products and calculate GHG emissions from R & AC	Data on national refrigerators production was obtained from MIDI while the imports figures were obtained from Customs.

1.12 Precursor Emissions from IPPU Sector

This section presents precursor emissions from the IPPU sector. The emission factor values were obtained from the EMEP/EEA 2019 Guidelines (EMEP/EEA, 2019) and the 1996 IPCC Guidelines.

Total Precursor emissions from the IPPU sector

NMVOCs Precursor Emissions

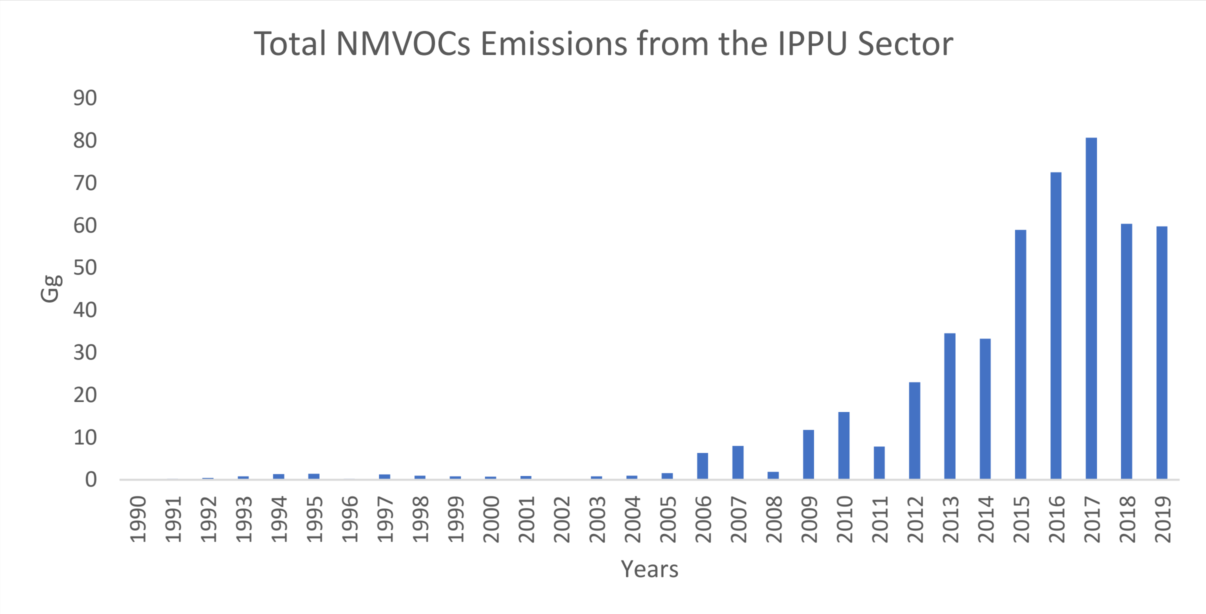

Figure 1-14: Total NMVOCs emissions from IPPU

Figure 1-14 presents total NMVOCs emissions from the IPPU Sector, excluding those recorded in 2H (Food and Beverages). NMVOC emissions were consistently low from 1990 to 2005, and increased gradually from 2006 to 2019, with a few noticeable declines in 2008 and 2011. The highest values were recorded in 2017, followed by a sharp decrease in 2018 and 2019. The increase of NMVOCs emissions from 2007 to 2019 can be attributed to the Industry sector development, as well as the fact that emissions from Lubricant use (2D1) were reported from 2007, Glass emissions were reported from 2008.

SO_2 Precursor Emissions

Figure 1-15 presents total SO_2 emissions from IPPU Sector. These emissions were only estimated from the Iron and Steel production (2C1) sub category. The emission levels were consistently low from 1996 to 2005, with a spike in 2006. From 2007 to 2010 the emissions were almost constant with a sharp increase from 2011 peaking in 2017. This was followed by constant emissions from 2018 up to 2020. The SO_2 emissions were calculated from the cement category. The 2017 emission levels represent a 93% increase from the 1996 levels.

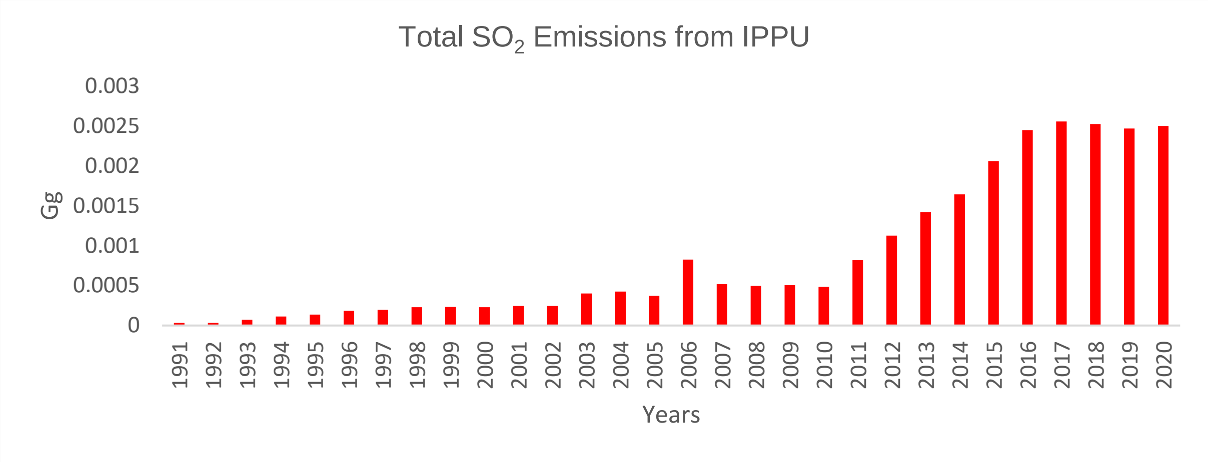

Figure 1-15: Total SO_2 Emissions from IPPU

Sub category precursor emissions

Lubricant Use (2D1) NMVOCs emissions

NMVOCs emissions from Lubricant use subcategory were fluctuating throughout the reporting period. There was a swift increase in the emissions in 2009 and 2010 and a rapid decline was experienced in 2011 followed by gradual fluctuations up to 2019. The 2019 emission levels depict a 66.7% decrease from the 2007 emission levels. The emissions peaked in 2010.

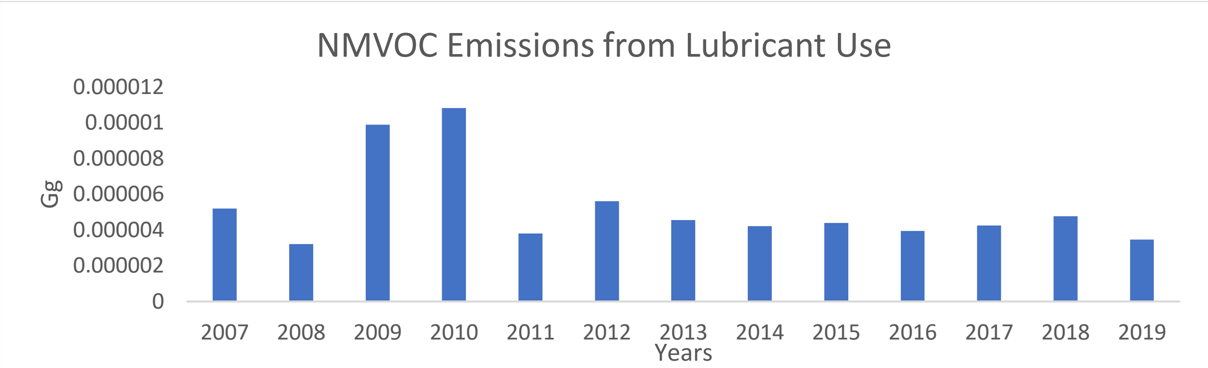

Figure 1-16: NMVOCs emissions from Lubricant Use (2D1)

Iron and Steel Production (2C1) NMVOCs emissions

NMVOC emissions from the iron and Steel Production sub category remained constant for the period 1990 to 2005, and gradually increased in 2006 and 2007. This was followed by a sharp drop in 2008 and a gradual fluctuating trend in emissions was experienced from 2009 to 2017. The highest emission levels were recorded in 2017, followed by a sharp decrease in 2018 and 2019.

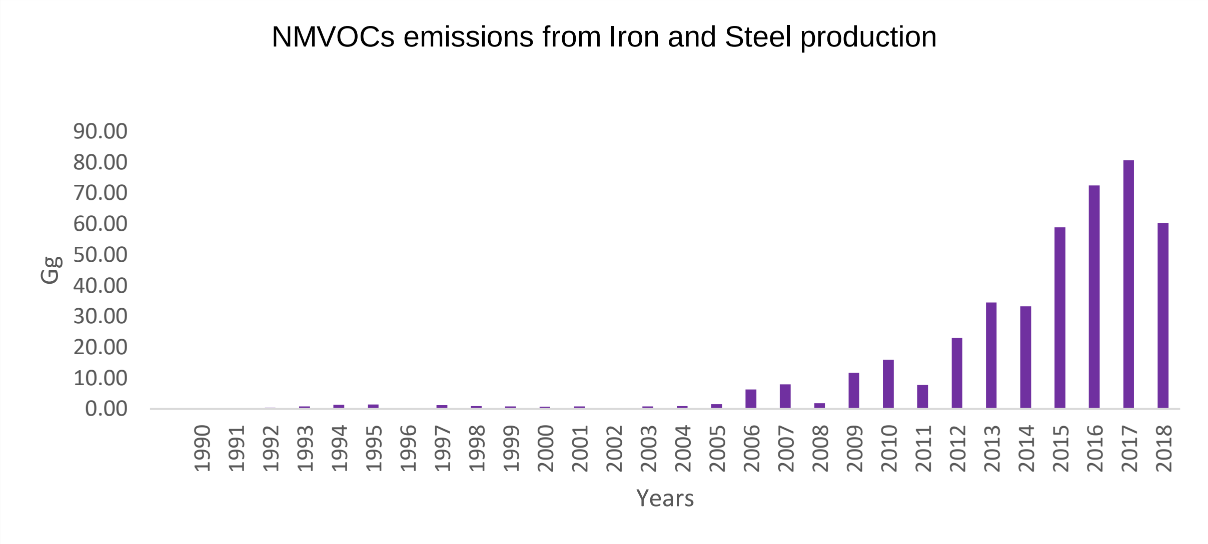

Figure 1-17: NMVOC emissions from Iron and Steel Production

Glass Production (2A3) NMVOCs emissions

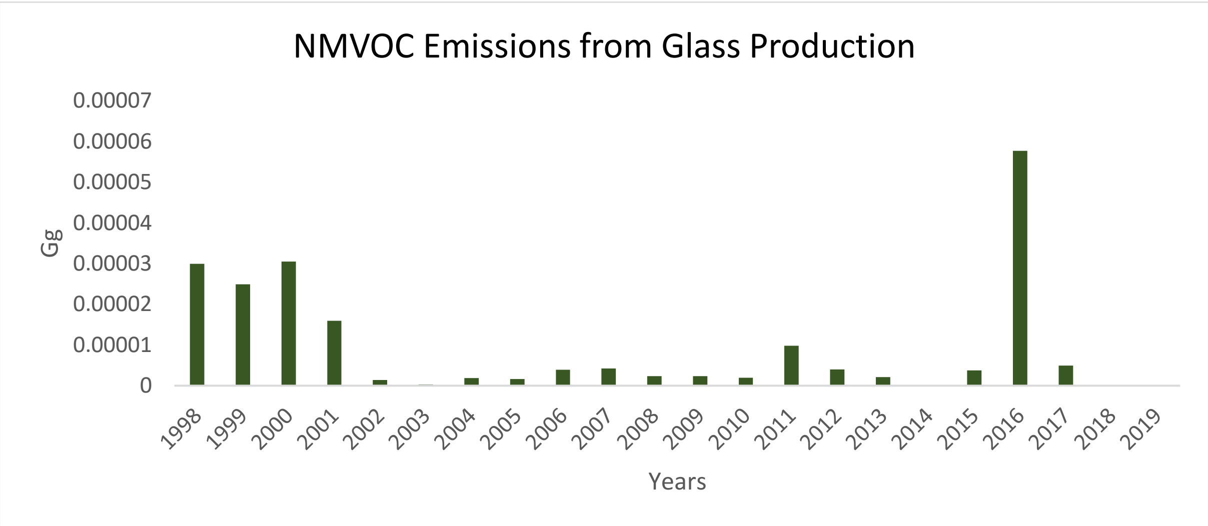

Figure 1-18: NMVOC Emissions from Glass Production

NMVOCs emission from Glass production reported from 1998 to 2001 were around 0.000020 Gg. There was a sharp decline in NMVOCs emissions in the period from 2001 to 2015 with intermittent spikes in between followed by a sudden increase in 2016 to around 0.000056Gg. In 2017 there was a sharp decline in the emissions.

2 Summary

Ethiopia's IPPU sector GHG emissions cover the period 1990 to 2019. Tier one methodology was applied on all categories, owing to data availability challenges. The Activity data provided was not sufficient to calculate GHG emissions using higher tier methodologies. Tier 2 data was available for one year in the cement sector, making it impossible to apply it in the calculations. The emission factors were obtained from the 2006 IPCC Guidelines, except for those for food and beverages that were obtained from EMP/CORIAIR Guidebook for 2019. Main Activity data sources were the CSA, Ethiopian Customs and Government Institutions such as CCIIDI, MIDI and the Ozone Secretariat. However, there were missing data for some years, and interpolation and extrapolation were used to cover the gaps in such cases. There were inconsistences in the data for glass, lime as well as food and beverages production, hence it could not be extrapolated. CSA data for the year 2001 was missing and interpolation was used to cover the year. The Global Warming Potentials from the IPCC Second Assessment report were used. In 2017, which is the reporting year for the TNC, CO_2 emissions accounted for the bulk (98.29%) of the GHG emissions from IPPU. HFCs contributed below 2%. Cement production was the major source of emissions over the years in Ethiopia's IPPU sector. For major improvements, there is need to collect sufficient data for higher level tier methodologies, especially for key categories, notably cement. There is also need to Develop and implement a category specific QA/QC plan.

3 References

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4 ANNEXES

ANNEX A: Glass bottles

		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Glass Bottles	('000 PCS)	143,820	219,743	269,021	140691.5	12,362	2,647	16,658	14,681	34,135	37,333
	Actual # (*1000 PCS)	143,820,000	219,743,000	269,021,000	140,691,500	12,362,000	2,647,000	16,658,000	14,681,000	34,135,000	37,333,000
Average weight of a bottle	>Kg (*0.2268)	32,618,376	49,837,712	61,013,962	31,908,832	2,803,701.6000	600,339	3,778,034	3,329,650	7,741,818	8,467,124
Conversion to tonnes	>tonnes (/1000	32,618.38	49,837.71	61,013.96	31,908.83	2,803.70	600.34	3,778.03	3,329.65	7,741.82	8,467.12
From IPCC default	Cullet value (*0.4)										

		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Glass Bottles	('000 PCS)	20,801	20,410	16,584	26,089	32,081	18,785	-	33,886	482,697	2,872
	Actual # (*1000 PCS)	20,801,000	20,410,000	16,584,000	26,089,000.	32,081,000	18,785,000		33,886,000	482,697,000	2,872,000
Average weight of a bottle	>Kg (*0.2268)	4,717,666	4,628,988	3,761,251	5,739,580	7,057,820	4,132,700	-	7,454,920	106,193,340	631,840
Conversion to tonnes	>tonnes (/1000	4,717.67	4,628.99	3,761.25	5,739.580	7,057.820	4,132.700	0.000	7,454.920	106,193.340	631.840
From IPCC default	Cullet value (*0.4)										

Source: CSA, 2020

Annex B: Glasses

		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Glasses	('000 PCS)	2,731	-	-		-	-	-	-	-	-
	Act # (*1000)	2,731,000									
Average weight of piece	>Kg (*10)	27,310,000									
Conversion to tonnes	>t (/1000)	27,310									
From IPCC default	Cullet value (*0.4)	32,618.4									
		59,928.38									

		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Glasses	('000 PCS)	-	-	26	1,394	93	-	-	-	919	919
	Act # (*1000)	-	-	26,000	1,394,000	93,000				919,000	919,000
Average weight of piece	>Kg (*10)	-	-	260,000	13,940,000	930,000				9,190,000	9,190,000
Conversion to tonnes	>t (/1000)	-	-	260	13,940.000	930.000	0.000	0.000	0.000	9,190.000	9,190.000
From IPCC default	Cullet value (*0.4)	-	-	130.0			0.000	0.000	0.000		
				3,761.25							

Source: CSA, 2020

Annex C: Brick of clay

		1998	1999	2000	2001	2002	2003	2004	2005	2006
Bricks of Clay	('000 PCS)	19,789	19,410	20,152	21131.5	22,111	20,961	14,334	24,785	13,893
	*1000(Actu PCS	19,789,000	19,410,000	20,152,000	21,131,500	22,111,000	20,961,000	14,334,000	24,785,000	13,893,000
Average mass of a brick	>KG (*1.88kg)	37,203,320.00	36,490,800.00	37,885,760.00	39,727,220.00	41,568,680.00	39,406,680.00	26,947,920.00	46,595,800.00	26,118,840.00
Conversion to tonnes	>T(/1000)	37,203.32	36,490.80	37,885.76	39,727.22	41,568.68	39,406.68	26,947.92	46,595.80	26,118.84
From IPCC default	>losses (*1.1)	40,923.65	40,139.88	41,674.34	43,699.94	45,725.55	43,347.35	29,642.71	51,255.38	28,730.72

		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Bricks of Clay	('000 PCS)	44,957	13,909	13,087	17,645	18,408	13,976	1,441	12,223	1,053	4,324	9,119
	*1000 (Actual PCS	44,957,000	13,909,000	13,087,000	17,645,000	18,408,000	13,976,000	1,441,000	12,223,000	1,053,000	4,324,000	9,119,000
Average mass of a brick	>KG (*1.88 kg)	84,519,160.00	26,148,920.00	24,603,560.00	33,172,600.00	34,607,040	26,274,880	2,709,080	22,979,240	1,979,640	8,129,120	17,143,720
Conversion to tonnes	>T (/1000)	84,519.16	26,148.92	24,603.56	33,172.60	34,607.040	26,274.880	2,709.080	22,979.240	1,979.640	8,129.120	17,143.720
From IPCC default	>losses(*1.1)	92,971.08	28,763.81	27,063.92	36,489.86	38,067.744	28,902.368	2,979.988	25,277.164	2,177.604	8,942.032	18,858.092

Source: CSA, 2020

Annex D: Cement floor tiles

		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Cement Floor Tiles	SQ.M	368,328	340,652	551,107	386454	221,801	395,916	245,696	485,868	953,011	465,779
Average per square metre	>kg(*20)	7,366,560	6,813,040	11,022,140	7,729,080	4,436,020	7,918,320	4,913,920	9,717,360	19,060,220	9,315,580
Conversion to tonnes	>t(/1000	7,366.56	6,813.04	11,022.14	7,729.08	4,436.02	7,918.32	4,913.92	9,717.36	19,060.22	9,315.58
From IPCC default	>losses (*1.1)	8,103.22	7,494.34	12,124.35	8,501.99	4,879.62	8,710.15	5,405.31	10,689.10	20,966.24	10,247.14

		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Cement Floor Tiles	SQ.M	287,257	112,616	199,092	413,731	776,566	190,112	896,762	623,631	5,776,737	1,095,133
Average per square metre	>kg (*20)	5,745,140	2,252,320	3,981,840	8,274,620	15,531,320	3,802,240	17,935,240	12,472,620	115,534,740	21,902,660
Conversion to tonnes	>t (/1000	5,745.14	2,252.32	3,981.84	8,274.620	15,531.320	3,802.240	17,935.240	12,472.620	115,534.740	21,902.660
From IPCC default	>losses (*1.1)	6,319.65	2,477.55	4,380.02	9,102.082	17,084.452	4,182.464	19,728.764	13,719.882	127,088.214	24,092.926

Source: CSA, 2020

ANNEX E: Summary on use of ODS alternatives

Alternative		Metric tonne			
		2012	2013	2014	2015
HFC					
HFC-134a		25.24	29.24	29.64	33.94
HFC-32		-	-	-	-
HFC-152a		-	-	-	-
HFC-245fa		3.32	6.65	12.94	13.23
HFC-227ea/HFC-365mfc		-	-	-	-
Others (specify)		-	-	-	-
HFC blends					
R-404A		8.1	20.1	16.52	19.32
R-407C		14.22	22.14	20.02	25.5
R-410A		450	797.20	1397	2106
R-507A		-	-	-	-
Others (specify)		56.34	32.7	33.77	11.26
HFO					
HFO-1234yf		-	-	-	-
HFO-1234ze		172.04	172.99	185.31	196.24
HFO-1233zd		19.59	20.09	45.29	56.99
HFO-1336mzzm			-	-	-
Other alternative					
Methyl formate		-	-	-	-
Methylal		-	-	-	-
Ethanol(m^3)		1,734,884	1,854,915.49	1,662,989	1,769,209.36
DME		-	-	-	-
HC-290		-	-	-	-
HC-600a		-	-	-	-
Pentane(C,N,I)		-	-	-	-
R-744		786.22	381.99	352.51	1,834.4
R-717		69.52	27.44	59.02	66.05
Others	Methylchloride	407	367.63	355.47	267.18
	Hydrocarbon	12.56	30.65	23.99	65.8

ANNEX F: Imported ODS alternatives

Alternative		Metric tonne			
		2012	2013	2014	2015
HFC					
HFC-134a		25.24	29.24	29.64	33.94
HFC-32		-	-	-	-
HFC-152a		-	-	-	-
HFC-245fa		3.32	6.65	12.94	13.23
HFC-227ea/HFC-365mfc		-	-	-	-
Others (specify)		-	-	-	-
HFC blends					
R-404A		8.1	20.1	16.52	19.32
R-407C		14.22	22.14	20.02	25.5
R-410A		450	797.20	1397	2106
R-507A		-	-	-	-
Others (specify)		56.34	32.7	33.77	11.26
HFO					
HFO-1234yf		-	-	-	-
HFO-1234ze		172.04	172.99	185.31	196.24
HFO-1233zd		19.59	20.09	45.29	56.99
HFO-1336mzzm			-	-	-
Other alternative					
Methyl formate		-	-	-	-
Methylal		-	-	-	-
Ethanol(m^3)		14,452.0	14,683.49	20,465	19,805.36
DME		-	-	-	-
HC-290		-	-	-	-
HC-600a		-	-	-	-
Pentane(C,N,I)		-	-	-	-
R-744		0.12	0.1	0.47	1.04
R-717		69.52	27.44	59.02	66.05
Others	Methyl chloride	407	367.63	355.47	267.18
	Hydrocarbon	12.56	30.65	23.99	65.8

Annex G: Precursor Emission Factors

2A1 Cement Production

Emission factor	Source	Comment
0.3 kg SO2/tonne cement.	Revised 1996 IPCC Guidelines for national GHG Inventories: Workbook	Default emission factor was applied

2A3 Glass Production

Emission factor	Source	Comment
NMVOCS 0.5 kg SO2/tonne of product	Revised 1996 IPCC Guidelines for national GHG Inventories: Workbook	Default emission factor was applied

2A Iron and Steel

Emission factor	Source	Comment
NMVOC 150g/Mg	EMEP/EEA 2019 Guidelines	Default emission factor was applied

2D1 lubricant use

Emission factor	Source	Comment
NMVOC 2 kg/Mg	EMEP/EEA 2019 Guidelines	Default emission factor was applied

5 IPPU Sector QC checks

QA/QC Procedures Applied

When compiling the inventory in Ethiopia, inventory quality is controlled by performing QC activities (such as checking the correctness of calculations and archive of documents) at each step in accordance with 2006 IPCC Guidelines. In Ethiopia, the QC activities relating to inventory compilation performed by personnel involved in inventory compilation, relevant ministries and agencies—are considered to be QC. External reviews by experts who are outside the inventory compilation system are considered to be QA. They assess data quality from the perspectives of scientific knowledge and data availability with respect to current calculation methods.

In accordance with Table 6.1, Chapter 6, Vol.1 of the 2006 IPCC Guidelines, general QC procedures include the general items to be confirmed which are related to the calculation, data processing, completeness, and documentation applicable to all emission source and sink categories. General QC procedures are implemented by each inventory compiler.

This section describes the QC activities of the Sectoral expert.

- Checking for transcription errors in data entry and referencing
- Checking to ensure that emissions are accurately estimated
- Checking to see that parameters and emission units are accurately recorded, and that proper conversion factors are used
- Checking the conformity of databases and/or files
- Checking the consistency of data from one category to another
- Checking the accuracy of inventory data behavior from one processing step to the next
- Checking completeness
- Checking time series consistency
- Checking trends
- Conducting comparisons with past estimated values
- Checking that uncertainties in emissions and removals are accurately estimated and calculated
- Carrying out reviews of internal documentation
- Checking that the assumptions and criteria for selecting AD and EFs are documented

IPPU Sector QC Activities

QC Activity	Procedures	Task Completed		Supporting Documents (List Document Name)
		Name/ Initials	Date	
Check that assumptions and criteria for the selection of activity data and emission factors are documented.	• Cross-check descriptions of activity data and emission factors with information on categories and ensure that these are properly recorded and archived.			
Check for transcription errors in data input and reference.	• Confirm that bibliographical data references are properly cited in the internal documentation (MDD template report) • Cross-check a sample of input data from each category (either measurements or parameters used in calculations) for transcription errors. • Utilize electronic data where possible to minimize transcription errors. • Check that spreadsheet features are use d to minimize user/entry error: • Avoid hardwiring factors into formulas. • Create automatic look-up tables for common values used throughout calculations. • Use cell protection so fixed data cannot accidentally be changed. ○ Build in automated checks, such as computational checks for calculations, or range checks for input data.			
Check that emissions/removals are calculated correctly.	• Reproduce a representative sample of emissions/removals calculations. • If models are used, selectively mimic complex model calculations with abbreviated calculations to judge relative accuracy.			
Check that parameter and emission/removal units are correctly recorded and that appropriate conversion factors are used.	• Check that units are properly labeled in calculation sheets and (MDD template report) • Check that units are correctly carried through from beginning to end of calculations. • Check that conversion factors are correct.			

QC Activity	Procedures	Task Completed		Supporting Documents (List Document Name)
		Name/ Initials	Date	
	• Check that temporal and spatial adjustment factors are used correctly.			
Check the integrity of database files.	• Confirm that the appropriate data processing steps are correctly represented in the database. • Confirm that data relationships are correctly represented in the database. • Ensure that data fields are properly labeled and have the correct design specifications. • Ensure that adequate documentation of database and model structure and operation are archived.			
Check for consistency in data between categories.	• Identify parameters (e.g., activity data, constants) that are common to multiple categories and confirm that there is consistency in the values used for these parameters in the emissions/removals calculations.			
Check that the movement of inventory data among processing steps is correct.	• Check that emissions/removals data are correctly aggregated from lower reporting levels to higher reporting levels when preparing summaries. • Check that emissions/removals data are correctly transcribed between different intermediate products.			
Review of internal documentation and archiving.	• Check that there is detailed internal documentation to support the estimates and enable duplication of calculations. • Check that every primary data element has a reference for the source of the data (via cell comments or another system of notation). • Check that inventory data, supporting data, and inventory records are archived and stored to facilitate detailed review. • Check that the archive is closed and retained in secure place following completion of the inventory • Check integrity of any data archiving arrangements of			

QC Activity	Procedures	Task Completed		Supporting Documents (List Document Name)
		Name/ Initials	Date	
	outside organizations involved in inventory preparation.			
Check methodological and data changes resulting in recalculations.	• Check for temporal consistency in time series input data for each category. • Check for consistency in the algorithm/method used for calculations throughout the time series. • Reproduce a representative sample of emission calculations to ensure mathematical correctness.			
Check time series consistency	• Check for temporal consistency in time series input data for each category. • Check for consistency in the algorithm/method used for calculations throughout the time series. • Check methodological and data changes resulting in recalculations. • Check that the effects of mitigation activities have been appropriately reflected in time series calculations.			
Check completeness	• Confirm that estimates are reported for all categories and for all years from the appropriate base year over the period of the current inventory. • For subcategories, confirm that the entire category is being covered. • Proved clear definition of 'Other' type categories. • Check that known data gaps that result in incomplete category emissions/removals estimates are documented, including qualitative evaluation of the importance of the estimate in relation to total net emissions (e.g. subcategories classified as 'not estimated').			
Trend checks	• For each category, compare current inventory estimates to previous estimates, if available. If there are significant changes or departures from expected trends, re-check estimates and explain any difference. Significant changes in			

QC Activity	Procedures	Task Completed		Supporting Documents (List Document Name)
		Name/ Initials	Date	
	emissions or removals from previous years may indicate possible input or calculation errors. • Check value of implied emission factors (aggregate emissions/removals divided by activity data) across time series. Are changes in emissions or removals being captured? • Check if there any unusual or unexplained trends noticed for activity data or other parameters across the time series.			