Addis Ababa City
2016 Greenhouse Gas Emissions Inventory Report

Version v8.0

The GHG Emissions Inventory Report was developed following the completion of Addis Ababa's 2016 GHG Inventory. It summarizes the city-wide GHG emissions sources by sector and scope, providing estimates for the sectors and methodologies applied to calculate the emissions.

Document Information

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List of Acronyms

AAEPGDC	Addis Ababa Environment Protection and Green Development Commission
AFOLU	Agriculture, forestry, and other land use
AR4	4th Assessment Report of the IPCC
C40	C40 Cities Climate Leadership Group
CAP	Climate Action Planning
CIRIS	City Inventory Reporting and Information System (CIRIS)
CRGE	Climate Resilience Green Economy Strategy
GDP	Gross Domestic Product
GHG	Greenhouse gas emissions
GPC	Global Protocol on Community-Scale Greenhouse Gas Emission Inventories
GWP	Global Warming Potential
ICLEI	Local Governments for Sustainability
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial processes and product use
M&P	Measurement and Planning
QA	Quality Assurance
QC	Quality Control
tCO2e	ton of Carbon dioxide equivalent
WRI	World Resources Institute

Preface

The Greenhouse Gas (GHG) emissions inventory report for Addis Ababa (Addis) has been prepared as part of C40's Global Climate Action Planning (CAP) programme, which Addis Ababa is part of from the 11 cities in Africa. The report summarises the results of the city's GHG inventory for 2016, which has been completed and confirmed as being compliant with the Global Protocol on Community-Scale Greenhouse Gas Emission Inventories (GPC) Standard by C40 Cities. This report documents GHG emissions by sector and scope within the city boundary.

The geographical boundary for the city covers the entire administrative area of Addis Ababa (an area of 540 km^2), with 10 sub-cities, namely, Addis Ketema, Akaky Kaliti, Arada, Bole, Gullele, Kirkos, Kolfe Keronio, Lideta, Nifas Silk-Lafto, and Yeka. The inventory report summarises the city-wide GHG emissions estimates for 2016, covering the transport, waste and energy sectors.

Additional information for this section

The GHG inventory has been compiled by Addis Ababa Environment Protection and the Green Development Commission (AAEPGDC), with technical assistance from C40 and Ricardo Energy & Environment. The city also acknowledges the positive support and advice from all stakeholders who have contributed to the compilation of the GHG inventory. A list of the contributors can be found in Appendix 1.

Some of the results presented in this report have been adjusted from those presented in the preliminary analysis, as methods were refined, errors were corrected, and new information was incorporated. This analysis is not intended to account for every emissions source attributable to Addis Ababa, rather it attempts to provide an accurate, credible, and policy-relevant baseline emissions inventory for 2016.

About the 2016 GHG Inventory

The 2016 GHG Inventory has been compiled in accordance with the GPC Standard and reported using C40's City Inventory Reporting and Information System (CIRIS) Tool. The inventory report summarizes the city-wide GHG emissions estimates for 2016**.** The 2016 GHG Inventory follows the city's first, which was prepared in 2012 and published in 2015.

The inventory estimates GHG emissions arising from Addis in 2016 totaled 14,479,133 tCO_2e. This estimation covers the energy, transport and waste sectors, with the biggest sectoral emissions emanating from the transport sector, followed by waste and building energy.
The results of the analysis will be submitted to various relevant actors at the city, national and international level, to facilitate decision making with regards to policy, strategy, planning and action development, with the aim of achieving a carbon neutral economy in Addis.

The city plans to update the GHG emissions inventory at least every 2 to 3 years with the latest data available. In the future, the city envisions the possibility of preparing an inventory every year as the MRV system for the city strengthens the data availability to undertake the emissions measurement improves. In addition, there will be a need to improve methodologies and backdate emission estimates to ensure a consistent time series. This could be done to account for better data sources, new guidance and new research.

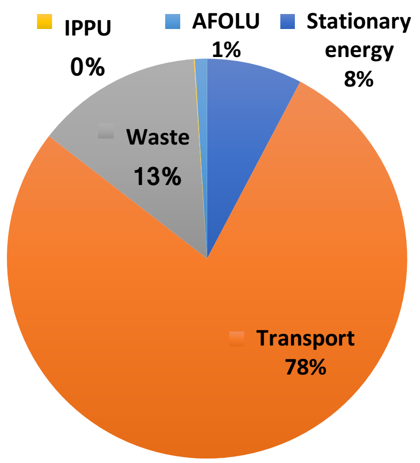
Executive Summary

Addis Ababa has a vision to create a clean, resilient and livable city for its inhabitants. The city recognizes that it is difficult to meet the vision without incorporating climate change into city plan and action agenda. One of the actions the city is taking in the quest to address climate change is taking stock of the city's GHG emissions, through the preparation of an emissions inventory, which will be used as a baseline to track city climate actions towards reducing emissions. The inventory encompasses emissions from energy consumption in buildings, transport and waste.

Overview of Emissions by Sector

It is estimated Addis Ababa emitted 14.48 million tonnes CO_2e in 2016. The transport sector was found to be the highest emitter, accounting for 78% of the total emissions, followed by the waste sector at 13% and stationary energy sector at 8%. The high emissions in the transport sector can be attributed to the presence of older vehicles in the city and the inclusion of the aviation sector (Scope 3) in the analysis, which contributes 69 % of transport emissions. In the waste sector, open burning and incineration are the main sources of emissions. Biomass energy consumption was found to be a major source of emissions in the stationary energy sector.

Total, per capita and sectoral CO_2e emissions in Addis Ababa in 2016



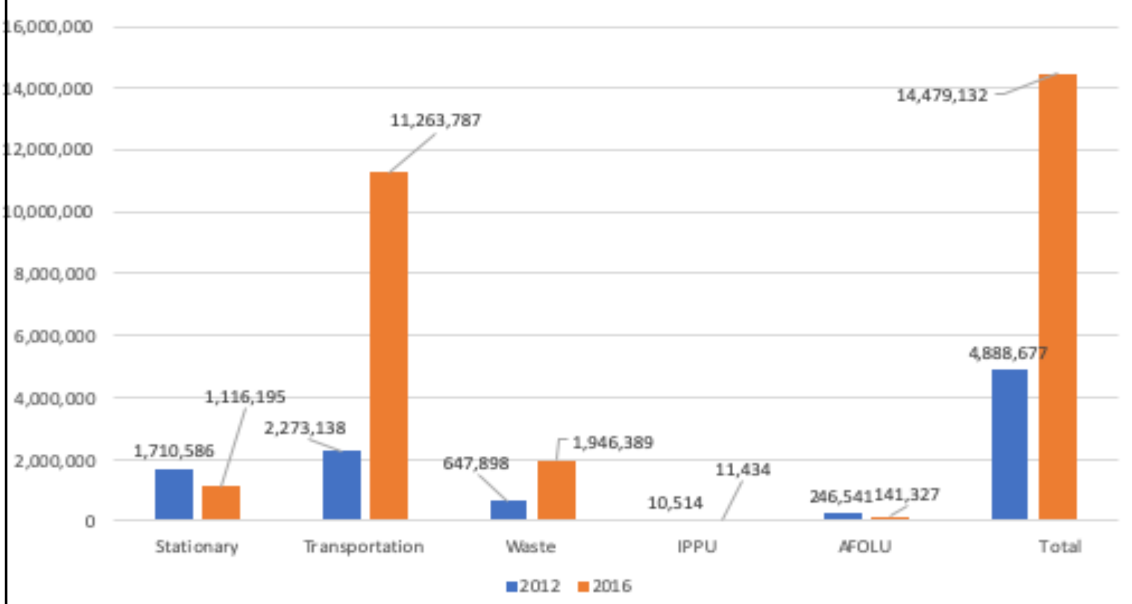
Total 2016 CO_2e emissions: 14.48 million-tonnes

Per capita 2016 CO_2e emissions:
4.3 t CO2e and 2,169 t CO2e per $US GDP

Comparison with previous years

An analysis of Addis Ababa's GHG emissions in 2016 indicated a 50 % increase in emissions compared with the first emissions inventory, prepared in 2012. The growth has been attributed to the rise in emissions from the transport and waste sectors, increasing by 66% and 13%, respectively.

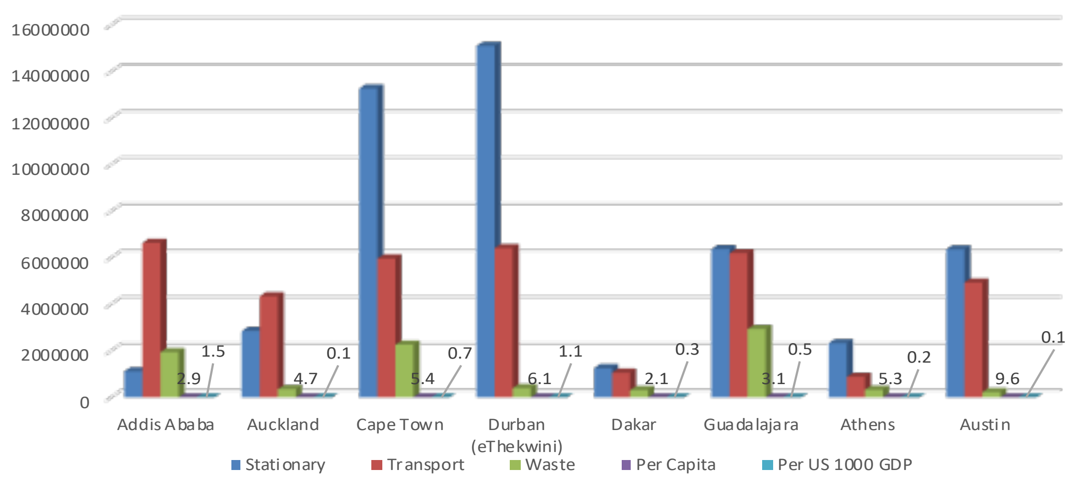
Comparison on the 2012 and 2016 GHG inventory



Comparison with other cities of the region

Addis Ababa's GHG emissions (BASIC) were compared with estimated emissions for 2016 from a range of mega cities from around the world, including Auckland (New Zealand), Cape Town (South Africa), Durban (South Africa), Dakar (Senegal), Guadalajara (Mexico), Athens (Greece) and Austin (USA). Addis was found to have the highest GHG emissions from the transport sector, whilst the waste sector was also amongst the highest. It is critical to note that Addis' per capita emissions are amongst the lowest, while the emissions per 1,000 USD amongst the highest in the region.

Sectoral and per capita emissions in Addis Ababa and other selected mega cities



1. Introduction

Greenhouse gases (GHGs) are the main cause of anthropogenic climate change. Multinational initiatives are vital to curb the challenge of climate change, due to the transboundary nature of the impacts. Following the Paris Agreement on climate change in 2015, 190 countries have agreed to limit their GHG emissions and take action on climate change. The Paris Agreement binds nations to limit their GHG emissions and strive for carbon-neutral economies by 2050, while enhancing climate change resilience.

Ethiopia is one of the countries to have signed the Paris Agreement and adopted the objectives through its Parliament. The nation has a Climate Resilience Green Economy Strategy (CRGE) that is aimed at reducing emissions by 64% in 2030 from the 2010 baseline. The CRGE will form an important part of the journey towards achieving carbon neutrality in 2050. Addis Ababa is taking bold actions in meeting the objectives of the Paris Agreement, and has signed the Deadline 2020 agreement with C40 Cities Climate Leadership Group (C40). Deadline 2020, which has been signed by 11 megacities in Africa, reflects the Paris Agreement at the city level, and aims to help cities to become climate resilient and carbon neutral by 2050.

A city-wide GHG inventory enables cities to measure their overall emissions, as well as understand the contribution of different activities within the city. This report summarises the results of the inventory for 2016, including emissions from the energy sector, used by different buildings types (such as residential, commercial, industrial etc.), energy used in the transport sector and waste sector related emissions.

The report is divided into five main chapters:

i. **Chapter 1** provides an overview of the methodology, emission sources, and the calculation and reporting processes undertaken.
ii. **Chapter 2** summarises the inventory compilation process including institutional arrangements, timeline of activities, inventory compilation and quality assurance process.
iii. **Chapter 3** presents a summary of the latest year emissions and emission trends, and reasons for changes from the previous inventory.
iv. **Chapter 4** presents the results for each sector in detail. The final section includes recommendations and improvements identified.

2. Methodology

This inventory was compiled following the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (also referred to as GPC) Standard, which is a GHG Protocol Standard developed by C40, World Resources Institute (WRI) and ICLEI – Local Governments for Sustainability. The GPC provides a robust framework for accounting and reporting city-wide GHG emissions. It seeks to:

- Develop a comprehensive and robust GHG inventory
- Establish a base year emissions inventory, set reduction targets and track their performance
- Ensure consistent and transparent measurement and reporting of GHG emissions between cities, following internationally recognised GHG accounting and reporting principles
- Enable cities' inventories to be aggregated at subnational and national levels
  Demonstrate the important roles that cities play in tackling climate change, and facilitate insight through benchmarking and aggregation of comparable data

GPC methodology

Activities taking place within a city can generate GHG emissions that occur inside as well as outside the city boundary. To distinguish among them, the GPC has grouped emissions into three categories based on where they occur: Scope 1, Scope 2 and Scope 3 emissions. Definitions are provided in Table 1, based on an adapted application of the Scopes Framework used in the GHG Protocol Corporate Standard.

Table 1: Scopes definition for city inventories

Scope	Definition
Scope 1	GHG emissions from sources located within the city boundary
Scope 2	GHG emissions occurring as a consequence of the use of grid-supplied electricity, heat, steam and/or cooling within the city boundary
Scope 3	All other GHG emissions that occur outside the city boundary as a result of activities taking places within the city boundary

The Scopes Framework helps to differentiate emissions occurring physically within the city (Scope 1), from those occurring outside the city (Scope 3) and those arising from the use of electricity, steam, and/or heating/cooling supplied by grids which may or may not cross city boundaries (Scope 2). Scope 1 emissions may also be termed "territorial" emissions because they occur discretely within the territory defined by the geographic boundary. Figure 1 illustrates which emission sources occur solely within the geographic boundary established for the inventory, which occur outside the geographic boundary, and which may occur across the geographic boundary.

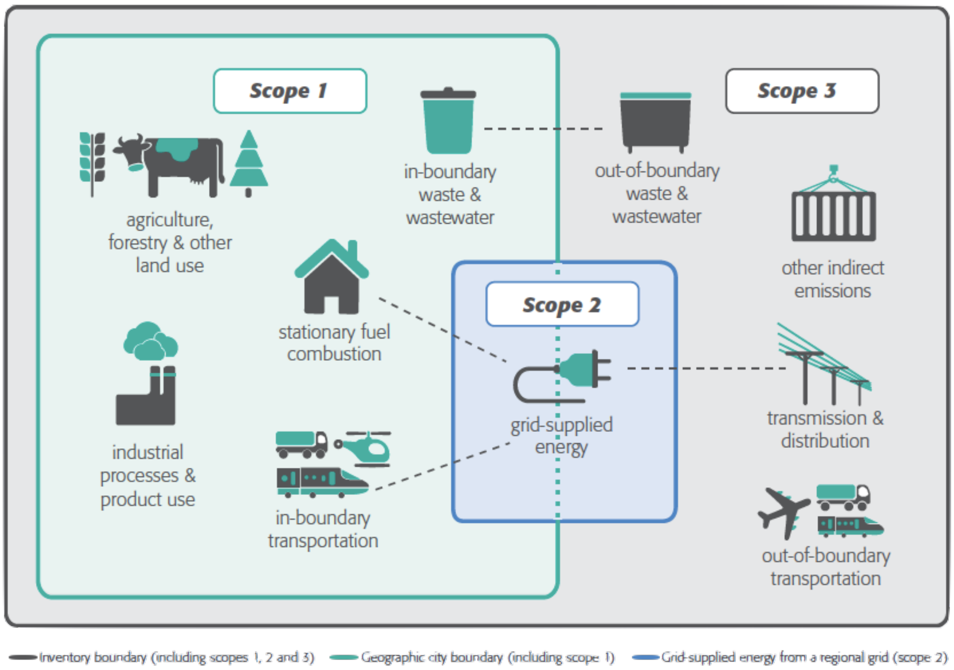


Figure 1: Sources and boundaries of city GHG emissions in GPC inventories

Emission calculation and reporting

Emissions are calculated by multiplying activity data (AD) by an emission factor (EF) associated with the activity. Activity data represents a quantity of an activity that results in GHG emissions during a given period of time (for example: kilowatt-hours (kWh) of electricity consumed within a year). Emission factors are used to calculate the quantity of GHG emissions generated for each unit of a specific activity (for example: tonnes of CO_2 emissions from the use of electricity, expressed as t CO_2/kWh). The City Inventory Reporting and Information System (CIRIS) Tool developed by C40 has been used calculate, monitor and report GHG emissions within the Addis Ababa, based on activity data, emission factors and other defaults data inputs.
In this inventory, emissions are classified into five main sectors as follows:

i. Stationary energy
ii. Transport
iii. Waste
iv. Industrial processes and product use (IPPU)
v. Agriculture, forestry, and other land use (AFOLU)

To accommodate limitations in data availability and differences in emission sources between cities, the GPC requires the use of notation keys, as recommended in IPCC Guidelines. The notation keys must be applied with an accompanying explanation to justify exclusion or partial accounting of GHG emission source categories, for example, if the activity does not occur or when sufficient activity data is unavailable. The notation keys are described Table 2.

Table 2: Use of notation keys

Notation key	Definition	Explanation
IE	Included Elsewhere	GHG emissions for this activity are estimated and presented in another category of the inventory. That category shall be noted in the explanation.
NE	Not Estimated	Emissions occur but have not been estimated or reported; justification for exclusion shall be noted in the explanation.
NO	Not Occurring	An activity or process does not occur or exist within the city.
C	Confidential	GHG emissions which could lead to the disclosure of confidential information and therefore cannot be reported.

The GPC also offers cities two levels of reporting demonstrating different levels of completeness. The BASIC level covers emission sources that occur in almost all cities (stationary energy, in-boundary transportation, and emissions from in-boundary generated waste, including waste disposed outside the boundary). The BASIC+ level has a more comprehensive coverage of emissions sources (BASIC sources plus IPPU, AFOLU, trans-boundary transportation, and energy transmission and distribution losses) and reflects more challenging data collection and calculation procedures. This GHG inventory reports data consistent with BASIC even if it has some data included for IPPU and AFOLU sectors (

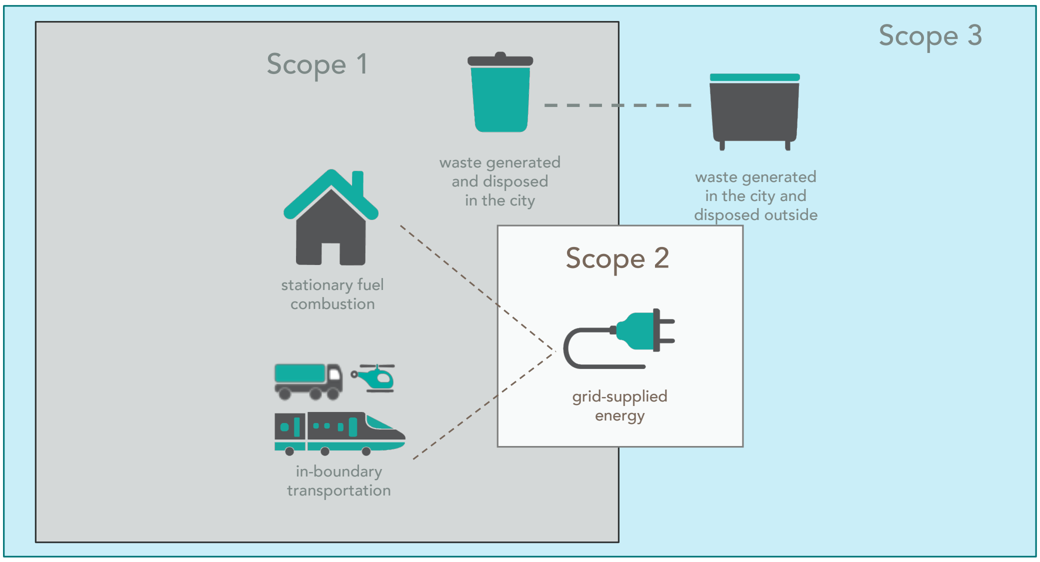


Figure 2).

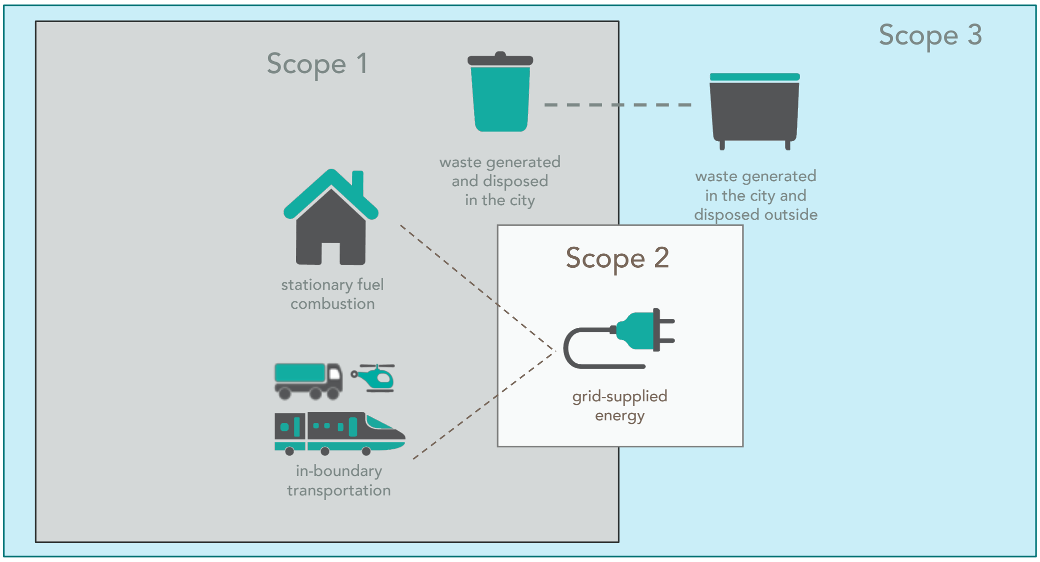


Figure 2: GPC reporting level - BASIC sources

Inventory boundary, GHG accounted and time span

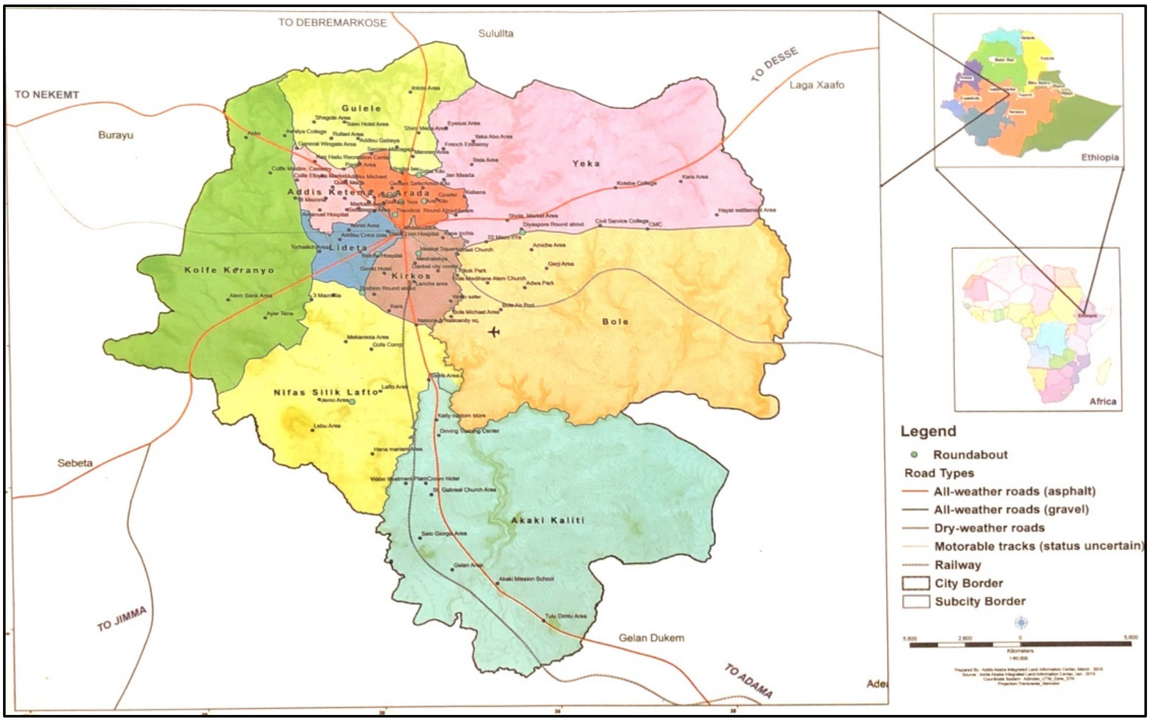
Inventory Boundary

Addis Ababa is the capital city of Ethiopia and hosts the head of the African Union, and regional and international organizations, including UN agencies and diplomatic missions. The city is located between 80 49’ 55.929’’ and 90 5’ 53.853’’ North latitude and between 380 38’ 16.555’’ and 380 54’ 19.547’’ East longitude. It is a city with an altitude ranging from 3,000 m (at Mt. Entoto) to 2050 m (at Akaki Plains). A map showing the location of Addis Ababa is shown in the Figure 3. Table 3: Facts about Addis Ababa provides key statistics on the climate, population, economy and geography of Addis Ababa.

Table 3: Facts about Addis Ababa

Climate	Mainly Woina Dega (Temperate Climate Feature)
Rainfall	Maximum: 1,250 mm; Minimum: 700 mm
Temperature	Average Maximum: 22.8 °C; Average Minimum: 10 °C
Population	3,353,000 (2016) – Addis Ababa makes up approximately 4% of total population in Ethiopia
Economic Activities	Trade 31%; manufacturing 23%; community services 14%; and the construction sector 12%
GDP	Approximately 6.6 billion USD; 8% GDP at the national level
Area	540 km^2
Administration	Governed by City Administration; 10 sub-cities; 117 Woredas

Figure 3: Map of the city’s boundary



Greenhouse gas

GHG include carbon dioxide (CO_2), methane (CH_4), Nitrous Oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). This GHG inventory covers emissions of CO_2, CH_4 and N_2O. The other four GHGs required by the GPC are considered negligible in Addis Ababa during the period of this inventory.

Time span

This GHG inventory was developed to reflect emissions during 2016. While Ethiopia follows the Julian calendar, this GHG inventory was developed based on the twelve-month cycle of Gregorian calendar to ensure international compatibility.

Summary of sources and activities covered by inventory

The sources and activities covered by this inventory are summarized in the table below, listed under scopes from 1 to 3. The tick mark (√) showed in the table represents the covered sources and activities and notation keys (e.g. NO = Not Occurring and IE = Included Elsewhere) provide further detail.

Table 4: Sources and activities covered by the inventory

Sectors and sub-sectors	Scope 1	Scope 2	Scope 3
Stationary energy			
Residential buildings	✓	NO	NO
Commercial buildings	✓	NO	NO
Institutional buildings	✓	NO	NO

Sectors and sub-sectors	Scope 1	Scope 2	Scope 3
Manufacturing industries and construction	✓	NO	NO
Energy industries	NO	NO	NO
Energy generation supplied to the grid	NO		
Agriculture, forestry, and fishing activities	✓	NO	NO
Non-specified sources	NO	NO	NO
Fugitive emissions from coal	NO		NO
Fugitive emissions from oil and natural gas systems	NO		NO
Transportation			
On-road	✓	NO	✓
Railways	NO	NO	NO
Waterborne navigation	NO	NO	NO
Aviation	NO	NO	✓
Off-road	IE	NO	NO
Waste			
Solid waste generated in the city	✓		NO
Solid waste generated outside the city	NO		
Biological waste generated in the city	✓		NO
Biological waste generated outside the city	NO		
Incinerated and burned waste generated in the city	✓		NO
Incinerated and burned waste generated outside city	NO		
Wastewater generated in the city	✓		NO
Wastewater generated outside the city	✓		
Industrial processes and product use (IPPU)			
Industrial processes	NO		NO
Product use	✓		NO
Agriculture, forestry, and fishing activities (AFOLU)			
Livestock	✓		NO
Land	NO		NO
Other agriculture	✓		NO
Other scope 3			

= sources required for reporting

= sources required for BASIC reporting

Sectors and sub-sectors	Scope 1	Scope 2	Scope 3

+ = sources required for BASIC+ reporting

= additional scope 1 sources required for territorial reporting

= other scope 3 sources

= non-applicable emission sources

3. Inventory Management and Compilation Process

Institutional arrangements for inventory management

The GHG Emission Inventory work was led by the Addis Ababa Environment Protection and Green Development Commission (AAEPGDC), with technical assistance provided by C40 and Ricardo Energy & Environment. The activity data for the inventory was gathered from different institutions at the city and national level. The institutions were classified into six categories, based on the types of data provided to undertake the inventory:

- Institutions 1 – data relevant to stationary energy
- Institutions 2 - data relevant to transport
- Institutions 3 – data relevant to waste
- Institutions 4 – data relevant to industrial processes and product use (IPPU)
- Institutions 5 – data relevant to agriculture, forestry and other land use (AFOLU)
- Institutions 6 – cross sectoral data (e.g. population, GDP statistics etc.)

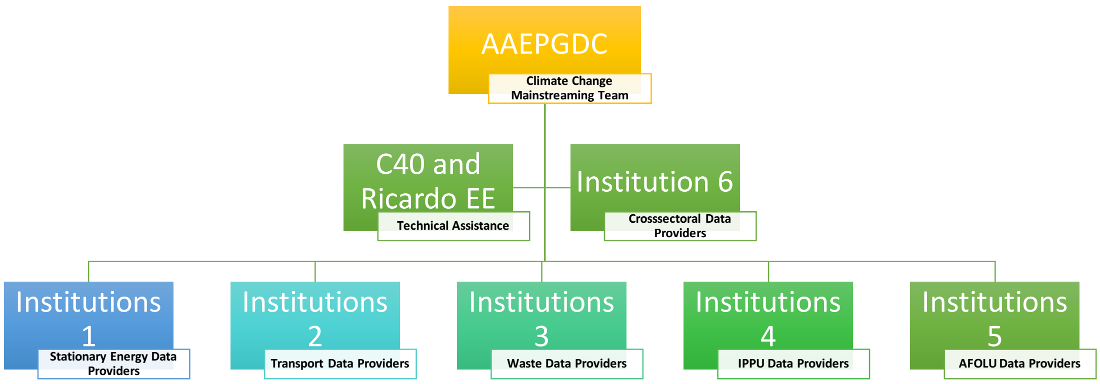


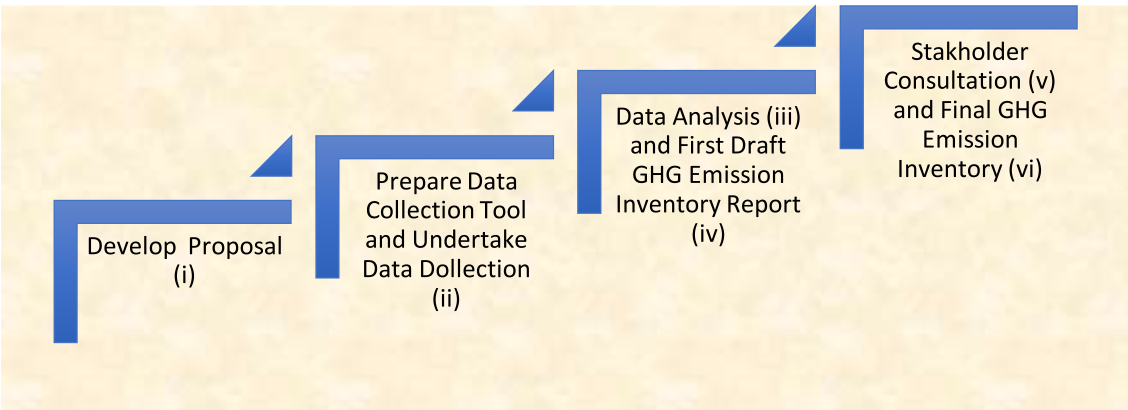
Figure 4: Overview of Institutional Arrangement for Inventory Management

Inventory compilation processes

The inventory compilation process has involved a six-step approach:

i. Proposal preparation
ii. Data collection
iii. Data analysis
iv. Draft GHG emission inventory report
v. Stakeholder consultation and
vi. Quality control and assurance

Figure 5: Overview of the GHG compilation steps



The steps are briefly discussed as follows:

Step i: Develop standard proposal: which outlines the approach, actors, roles, timeframe and budget for execution of the inventory. This was helpful to establish a common, shared approach with the inventory team.

Step ii: Undertake data collection: a data collection template was developed and data provider institutions were identified.

- **Data Collection Tool Preparation**: the data collection tool was prepared by the AAEPAGDC with technical assistance from C40 City Adviser. The data collection tool was reviewed by Ricardo Energy & Environment.
- **Data Collection**: through discussions with data providers.

Step iii / iv: Data analysis and first draft GHG emission inventory report: the data provided by institutions, secondary data sources and expert assumptions were analysed and entered in to the CIRIS tool to produce the first draft report.

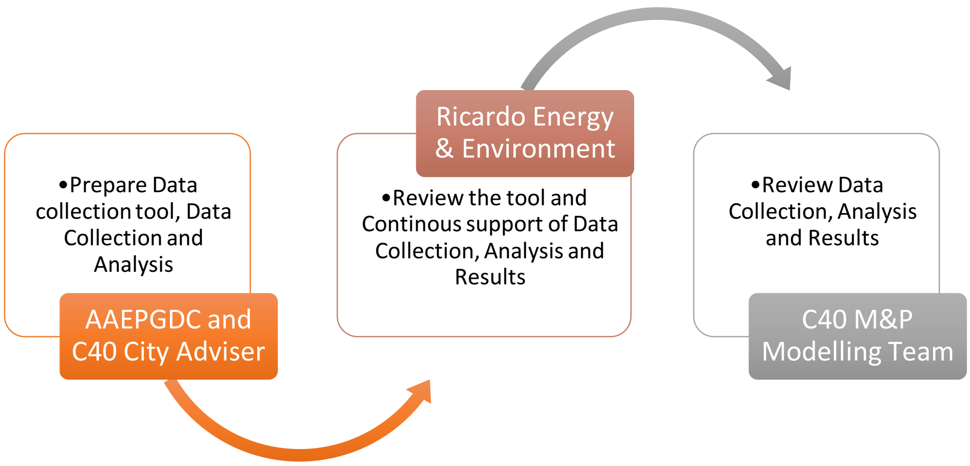
Step v: Organize stakeholder consultation for feedback and finalize the report: Stakeholder consultations with data providers and other relevant institutions.

Step vi: Quality control and assurance: After the inventory report was finalized, it was reviewed and validated by Ricardo Energy & Environment and the C40 Measurement and Planning team.

Inventory review and quality assurance processes

A Quality Control and Quality Assurance (QC/QA) procedure has been developed in support of the GHG emissions inventory. The AAEPGDC and C40 City Adviser are responsible for quality control. Quality assurance was conducted by Ricardo Energy & Environment and C40. The QC/QA procedure included a review of the data collection tool, data entry into CIRIS, and equations and conversion factors used to calculate GHG emissions. The overall results were checked in accordance with standard practices, ensuring reporting has been completed in accordance with GPC.

Figure 6: QC / QA Procedure



The quality of the activity data was rated against the three classifications under the GPC standard: high (H), medium (M) and low (L).

Table 5: Data Quality Checklist

Data quality	Activity data	Emission factor
High (H)	Detailed activity data	Specific emission factors
Medium (M)	Modelled activity data using robust assumptions	More general emission factors
Low (L)	Highly modelled or uncertain activity data	Default emission factors

4. Total Emissions and Trends

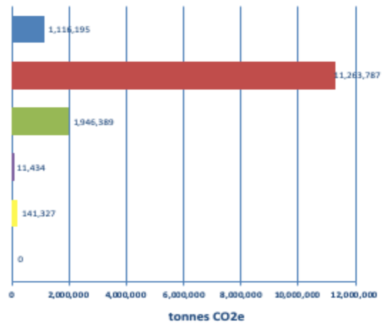
The total GHG emissions estimated for the Addis Ababa Municipal Area in 2016 was 14,479,133 tCO_2e. The largest contribution was found to be from the transportation sector (78% of the total GHGs), followed by waste emissions (13%) and stationery energy (8%). Figure 7 and

present the outputs from the CIRIS Tool, including total, sectoral, per capita and per GDP emissions.

SUMMARY

NAME OF CITY:	Addis Ababa, Ethiopia	POPULATION:	3,353,000
BOUNDARY:	BASIC	LAND AREA (km2):	540
INVENTORY YEAR:	2016	GDP (US$ million):	6,677

tCO2e	BASIC+	Scope 1	Scope 2	Scope 3
	Stationary	1,115,659	537	
	Transportation	6,641,237	3	4,622,548
	Waste	1,946,389		
	IPPU	11,434		
	AFOLU	141,327		
	Other Scope 3			
	TOTAL	14,479,133		



Intensity indicators	Per capita	Per unit land area (km2)	Per unit GDP (US$m)
Emissions	4.3	26,813	2,169

Figure 7: Summary analysis of GHG emissions

Scope 1 emissions are the highest, at 68 %, followed by the Scope 3 emissions at 32 %, which are mainly from the aviation sector. Scope 2 emissions are very small and are related to electricity consumption in buildings and the Addis Ababa LRT.

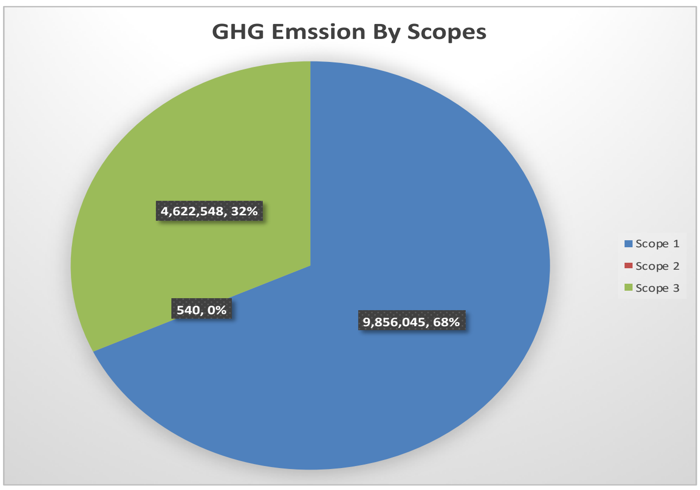


Figure 8: GHG emissions by Scope

Emissions by sub-sector

The sub-sector analysis showed that on-road transport accounted for 51% of the total city-wide GHG emissions. The aviation sector (under Scope 3) was the next highest contributing sub-sector, which contributed 26% of the total emissions. The third highest contributors to community emissions were found to be solid waste, incineration and waste burning, which contributed 11% of total emissions. Figure 9 below illustrates the total community emissions produced in the city by sub- sectors. A more in-depth breakdown of the sub- sectors per emission source can be found in chapter 4.

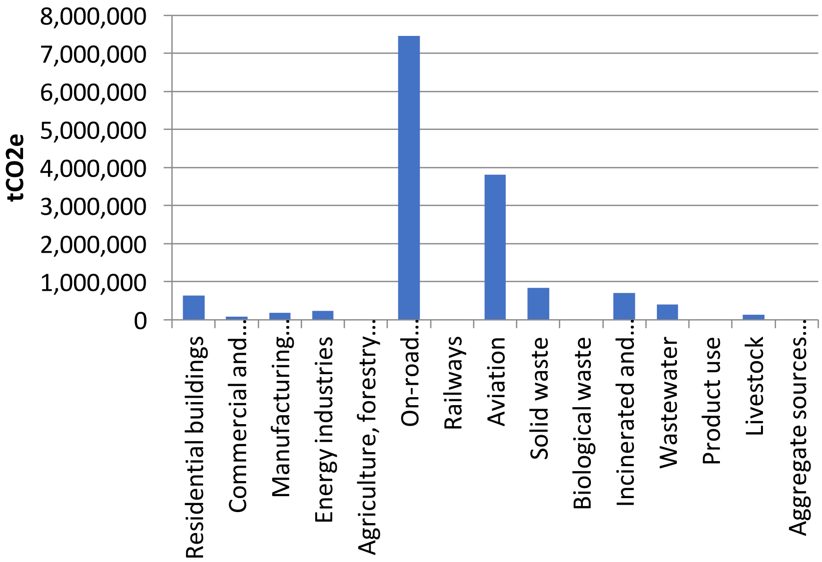


Figure 9: Overview of GHG emissions by sub-sector for 2016

Table 6: GHG emissions sources

I	STATIONARY ENERGY	Scope 1	Scope 2	Scope 3	Total
I.1	Residential buildings	629,821	230	NE	630,051
I.2	Commercial and institutional buildings and facilities	78,052	132	NE	78,184
I.3	Manufacturing industries and construction	180,823	174	NE	180,997
I.4.1/2/3	Energy industries	224,902	NO	NO	224,902
I.4.4	Energy generation supplied to the grid	NO			
I.5	Agriculture, forestry and fishing activities	2,061	NO	NO	2,061
I.6	Non-specified sources	NO	NO	NO	0
I.7	Fugitive emissions from mining, processing, storage, and transportation of coal	NO			0
I.8	Fugitive emissions from oil and natural gas systems	NO			0
SUB-TOTAL	(city induced framework only)	**1,115,659**	**537**	**0**	**1,116,195**
II	**TRANSPORTATION**				
II.1	On-road transportation	6,641,237	NO	814,298	7,455,535
II.2	Railways	NO	3	NE	3
II.3	Waterborne navigation	NO	NO	NE	0
II.4	Aviation	NO	NO	3,808,250	3,808,250
II.5	Off-road transportation	NO	NO	NO	0
SUB-TOTAL	(city induced framework only)	**6,641,237**	**3**	**4,622,548**	**11,263,787**
III	**WASTE**				
III.1.1/2	Solid waste generated in the city	836,120		NO	836,120
III.2.1/2	Biological waste generated in the city	3,956		NO	3,956
III.3.1/2	Incinerated and burned waste generated in the city	701,866		NO	701,866
III.4.1/2	Wastewater generated in the city	404,447		NO	404,447
III.1.3	Solid waste generated outside the city	NO			
III.2.3	Biological waste generated outside the city	NO			
III.3.3	Incinerated and burned waste generated outside city	NO			
III.4.3	Wastewater generated outside the city	NO			
SUB-TOTAL	(city induced framework only)	**1,946,389**		**0**	**1,946,389**
IV	**INDUSTRIAL PROCESSES and PRODUCT USES**				

IV.1	**Emissions from industrial processes occurring in the city boundary**	NE			0
IV.2	**Emissions from product use occurring within the city boundary**	11,434			11,434
SUB-TOTAL	(city induced framework only)	**11,434**			**11,434**
V	**AGRICULTURE, FORESTRY and OTHER LAND USE**				
V.1	**Emissions from livestock**	129,103			129,103
V.2	**Emissions from land**	NE			0
V.3	**Emissions from aggregate sources and non-CO2 emission sources on land**	12,225			12,225
SUB-TOTAL	(city induced framework only)	**141,327**			**141,327**
VI	**OTHER SCOPE 3**				
VI.1	**Other Scope 3**			NE	0
TOTAL	(city induced framework only)	**9,856,045**	**540**	**4,622,548**	**14,479,133**

Emission trends: comparison with previous years

The 2016 Addis Ababa GHG Inventory enables a comparison to be made with the previous emissions inventory, compiled in 2012. The emerging emissions trend is summarized in the table and graph below. As is evident from these datasets, there has been an increase in total GHG emissions in the city over this period. This trend is attributed to the inclusion of additional sub-sectors which were not found in the first inventory year, such as open burning. Other factors include improved data collection methodologies and an increase in the use of energy and carbon intensive processes in the city.

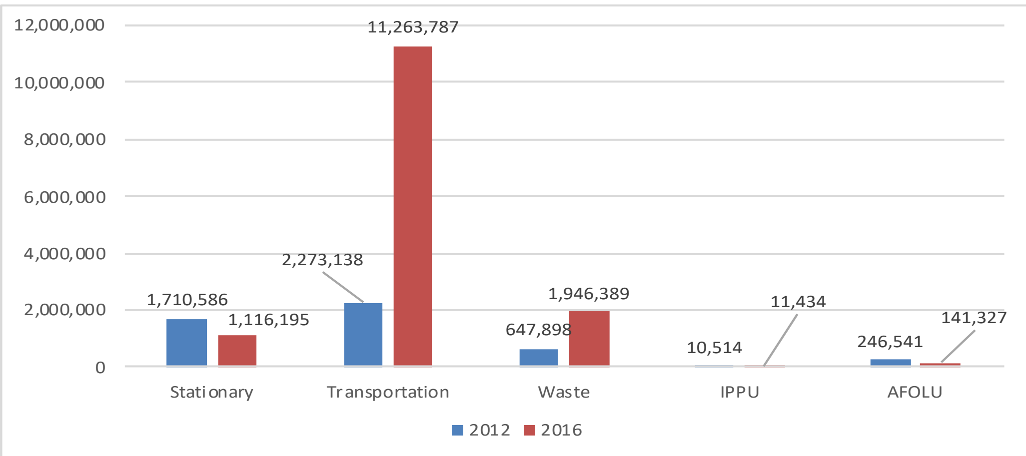


Figure 10: Comparison of the 2012 and 2016 GHG emission inventories

Overall, the inventory data suggests emissions have increased by 50% between 2012 and 2016. This is a result of the following:

- ↓ Emissions from stationery energy generation have decreased by 22%; this is due to improvements in generation efficiency, the grid factor, and switch from fuel to electricity consumption by residential buildings.
- ↓ Emissions from AFOLU are around 1% and 28% lower in 2016 than 2012 due to a reduction in total number of livestock and minimum application of fertilizer.
- ↑ Emissions from IPPU have increased by 4% between 2012 and 2016; this follows trends in national data that have been used as a proxy for the city's emissions from product use.
- ↑ Emissions from transport have increased by 66% due to more fuel being consumed by vehicles.
- ↑ Emissions from waste are around 13% and 50% higher in 2016 than 2012 due to a reduction in total waste arising sent to landfill and an increase in composting.

5. GHG Emissions by Sector

Stationary Energy

Buildings use a variety of energy sources, which can be categorized as biomass fuels, fossil fuels and electricity. The common biomass fuels used in the city include charcoal, wood, branch-leaves, twigs (BLT), dung and to some extent crop residue. With regards to fossil fuels, residential and commercial premises typically use kerosene and LPG. In the times of electricity interruption, diesel and back-up generators are used in the commercial and manufacturing sectors. Manufacturing industries commonly use furnace oil. City electricity is produced from hydro power and it is commonly used in all building types.

Emissions arising from the use of these energy sources are split into the following sub-sectors:

I. Residential buildings
II. Commercial and institutional buildings and facilities
III. Manufacturing industries and construction
IV. Energy industries
V. Agriculture, forestry and fishing activities

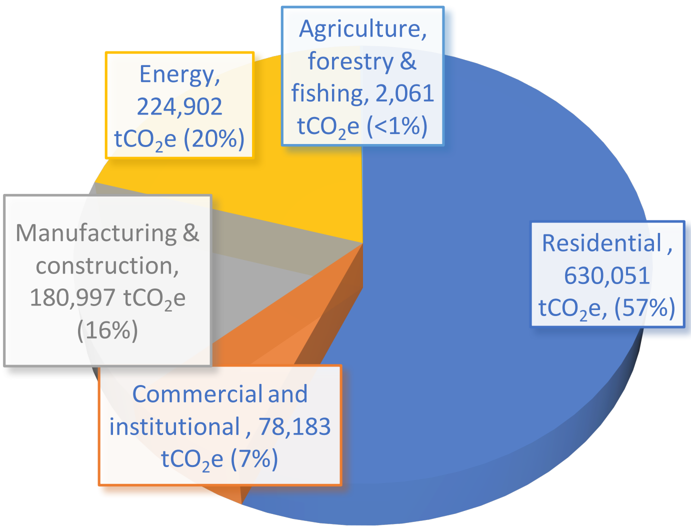


Figure 11: Stationary energy emissions by sub-sector

8% of the city's total GHG emissions (1,116,195 tCO_2e) arose from stationary energy combustion, which is the 3rd highest emission source in the city. Within this source category, residential energy contributed the highest emissions at 57% (630,051 tCO_2e), followed by energy industry (224,902 tCO_2e), manufacturing and construction (180,997 tCO_2e), and commercial and institutional buildings (78,183 tCO_2e). The following graph shows the contributions from stationery energy sub sectors.

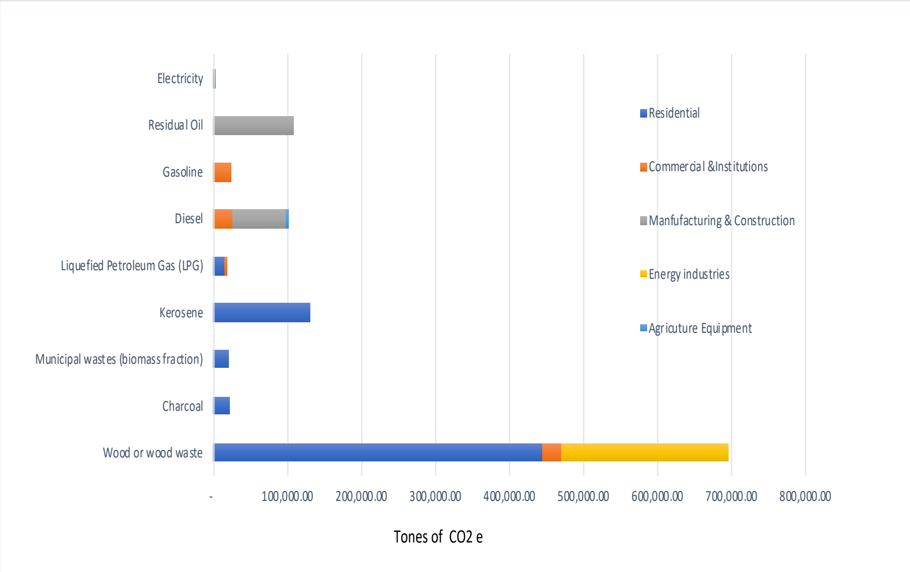


Figure 12: Stationary energy emissions by sub-sector and fuel type

Wood and wood waste is responsible for the majority of emissions from the stationary energy sector, followed by kerosene, residual fuel oil and diesel. A detailed description of the activity data, emissions and data sources for stationary energy can be found in Annex A1.

The following provides a brief description of each sub-sector:

Residential Buildings

The types of energy consumed in residential buildings include biomass (wood, branches, charcoal), kerosene, LPG and electricity. Residential buildings emitted 630,051 tCO_2e, representing 57% of emissions under stationery energy. Within the residential buildings subsector, most of the emissions are from the combustion of biomass (of which BLT account for 269,035 tCO2e and fuel wood for 119,445 tCO2e), followed by kerosene (129,986 tCO2e) and LPG 14,096 tCO2e . Besides electricity, residential buildings typically use biomass for cooking and other household activities such as boiling coffee and tea. Charcoal, tree branches, leaves, and twigs constitute the largest sources of biomass.

Commercial and Institutional Buildings

Commercial / institutional buildings are the fourth emitter among sub-sectors which emit 78,184 tCO2e (7%) in stationery energy. With respect to its fuel contribution to commercial and institutional buildings' emissions, fuel wood was by far the largest contributor, emitting 25,680 tCO2e in 2016 and accounting for 33% of the total sub-sector emissions. Following diesel-generators, gasoline-generators, LPG, electricity and street lighting electricity made significant contribution accounting for 32%, 30% and 5% respectively. The rest of the fuels (commercial electricity and street lighting electricity) together contributed less than 1%.

Manufacturing Industries and Construction

The fuel types included in the manufacturing and construction sub sector include furnace oil (heavy & light), diesel and electricity, resulting in emissions of 180,997 tCO_2e. Standby generators in the city combusted over 23,995,242 liters of diesel, emitting 68,676 tCO_2e. As for other fuel types and sources; heavy furnace oil, light furnace oil, off-road machinery and industry electricity accounted for 30%, 30%, 2% and <1% of total emissions respectively.

Energy industry

The energy industry is related to charcoal production. Emissions from charcoal totaled 224,902 tCO_2e. The energy industry contributed 20% of emissions arising from stationery energy.

Agriculture, forestry and fishing activity

In this inventory, off-road vehicles and other machinery have been reported under the agriculture, forestry and fishing activity sub sector. Emissions from diesel oils were 2,061 tCO_2e, and thus represent the lowest emitting sub sector in stationery energy.

Transport

Road, off-road, rail, water and air are the main means of transporting passengers or freight. The main transport type in Addis Ababa is on-road vehicles for passengers and freight. The city also has an electric powered light railway transit system, which covers a distance of approximately 34.5 km. Air travel connects Addis Ababa with national and international cities. Off-road transport is used in the manufacturing, construction and agriculture sectors. The emissions from the transport sector come from directly combusting fuel or indirectly consuming grid-delivered electricity. For transport occurring within the Addis Ababa, emissions from combustion of fuels are reported in Scope 1 and emissions from grid-supplied electricity are included in Scope 2. Scope 3 reports the emissions from a portion of transboundary journeys (aviation) occurring outside the city. The emissions are calculated for on-road vehicles, off-road vehicles, railways and aviation.

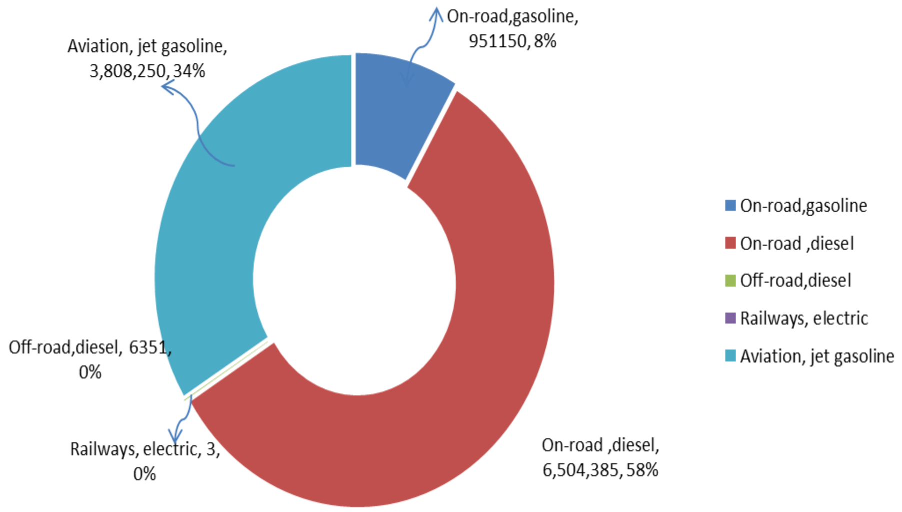


Figure 13: Transportation emissions by sub-sector

The transport sector accounts for 78% of Addis Ababa's GHG emissions in the 2016 inventory. On-road transport and aviation accounted for 66% and 34%, respectively, whilst off-road transport and railways contribute a small proportion.

Vehicles are the highest emitters at 7,461,886 tCO_2e, primarily from diesel at 58%, followed by petrol emissions at 42%, whereas aviation is the second largest emitting sector, with a total of 3,808,250 tCO_2e from jet gasoline.

The methodology and scope definition for the transport sector is as follows:

- **Scope 1** fuels include diesel, petrol and LPG for on-road vehicles. Emissions were calculated using a top-down fuel sales approach.
- **Scope 2** (grid-supplied energy) electric railway were negligible in Addis Ababa in 2016.
- **Scope 3** include aviation and trans-boundary movement of on-road transport.

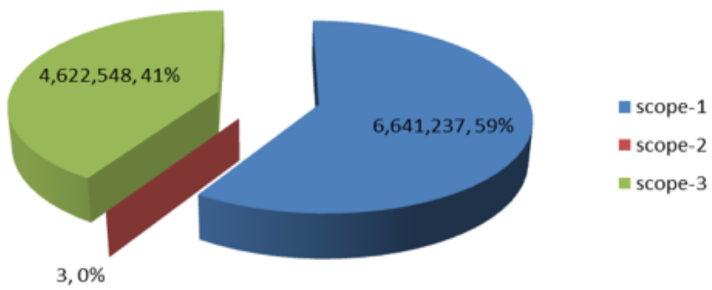


Figure 14: 2016 transport emission by scope definition

The relative emissions split between the different scopes are as follows: Scope 1 – 6,641,237 tCO_2e; Scope 2 – 3 tCO_2e; and Scope 3 – 4,622,548 tCO_2e. A detailed description of activity data, emission results and data sources can be found in Annex A2. The following provides a brief description of each sub-sector:

On-road Transport

Emissions from on-road transport accounted for 66% of the total 11,263,787 tCO_2e. Emissions from diesel vehicles is 650,4385 tCO_2e (87%) and gasoline is 951,150 tCO_2e (13%). Among on-road sub sectors, dry cargo (>10 quintals) is the largest contributor to emissions (3,454,950 tCO2e), followed by trailer vehicles, buses (< 12 seats), and dry cargo (<10 quintals), which accounted for 862,429.2 tCO_2e, 747,041 tCO_2e and 712,024.6 tCO_2e, respectively. The lowest emitting source was found to be three wheel dry loads, which accounted for 23.7 tCO_2e. Scope 1 GHG emissions included 6.64 $MtCO_2e$ from transportation occurring in the city boundary and Scope 3 GHG emissions included 814,298 tCO_2e from the out-of-city portion of trans-boundary trips that either originate or terminate within the city boundaries. The dry cargo, trailer, bus and automobiles are the highest emitters in order.

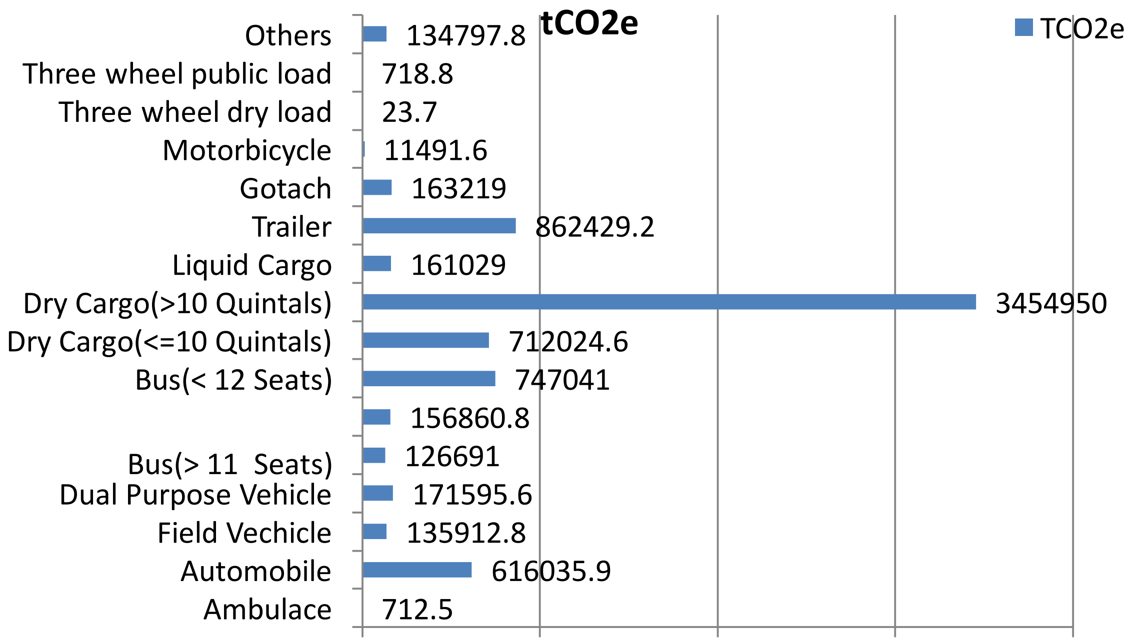


Figure 15: Emission by Vehicle Types

Railways

Emissions from the railway sector (LRT) were estimated using a top-down methodology and thus were based on the volume of electricity consumed. Scope 2 (grid-supplied energy) was considered to calculate electric railway emissions, which is totaled just 3 tCO_2e.

Aviation

Emissions from aviation comprise domestic and international flights. The domestic flights include passenger and freight traffic that departs and arrives within Ethiopia and the international flights include journeys made outside Ethiopia. Ethiopia has four international airports and 12 domestic airports. Addis Ababa city is dominated by domestic and international flights at Bole International Airport. This Airport in Addis Ababa is Ethiopia's largest airport and plays an important role in serving international passenger travels and freight transportation. All domestic and international trips originating from Bole International Airport are reported under Scope 3. The in-boundary aviation (Scope 1) was not accounted for as this was deemed negligible. GHG emissions from aviation represent the biggest contribution under Scope 3. International flights were found to account for the majority of emissions, contributing to 98% of the aviation total.

Off-road transport

The off-road category included vehicles and mobile machinery used within the agriculture, forestry, and industry (including construction) sectors. The vehicles / machinery types considered under the 2016 inventory included combiners, dozers, graders, forklifts, and tractors. Operational hours per year by vehicle type were multiplied by their respective fuel economy (litter per hour) to determine fuel consumption. The fuel consumptions by vehicles/ machinery type were then multiplied by relevant emission factors to estimate the quantity of GHG emissions.

In 2016, a total of 2,098,880 liters of diesel fuel was consumed by off-road transport in Addis Ababa, and the resulting emissions from the combustion of diesel was estimated to be 6350 tCO_2e, representing <1 % of emissions from the transport sector. When these emissions were distributed over the various types of off-road vehicles / machinery; machine-mounted vehicles accounted for the majority of GHG emissions (48%) and emissions from tractors accounted for 32%. Forklifts, dozers, combiners and graders accounted for the remaining 20% of off-road transport emission.

Waste

The city's Waste Management Agency is responsible for the coordination of municipal solid waste. Waste is collected by associations at the community level. Waste is collected from households and commercial institutions. Some areas are served by transfer stations, which enable the segregation and sorting of waste streams. The city has open dumpsites which have been serving the city for more than 50 years. The total municipal waste generated in the city in 2016 was 720,761 tonnes. The waste composition of Addis Ababa is dominated by organic material, which accounts for 64%. The remaining materials include plastics, metals and paper.

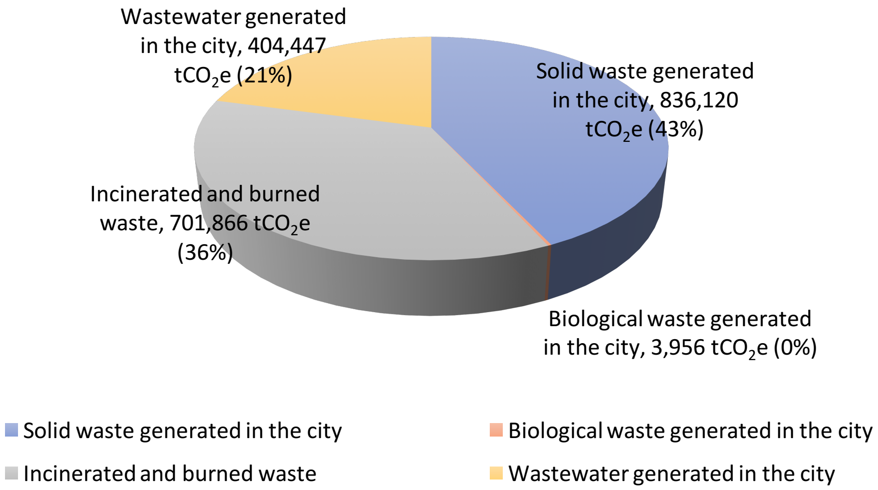


Figure 116: Waste emissions by sub-sector

Waste contributed 13% of Addis Ababa's GHG emissions in 2016. The waste sector is the second highest emitter in the city. Solid waste, incineration, waste burning and wastewater accounted for 43%, 36% and 21%, respectively, of the total 1,946,389 tCO_2e emitted, whereas biological waste contributed a lower proportion. A detailed description of the activity data, emissions results and data sources can be found in Annex A3. The following provided a brief description of each sub-sector:

Solid Waste

In 2016 Addis Ababa generated 720,761 tonnes of solid waste and disposed 438,223 tonnes in disposal sites (unmanaged landfills greater than 5m in depth, with no gas capture). Solid waste generation is the highest emitting source within the waste sector, at 43% (836,120 tCO_2e), followed by incineration and open burning.

Biological Treatment

A significant component of the waste collected in Addis Ababa is organic matter, which could be composted, but due to the mixed collection of waste, biological treatment is often not possible. In Addis Ababa, approximately 5% of organic waste is composted (23,064 tonnes), through household composting and some waste collector associations (selling compost for gardening), resulting in emissions of 3,956 tCO_2e in 2016.

Incineration and Open Burning

The proportion of organic matter in the waste steam presents challenges regarding the potential for treatment by incineration. If pre-treatment is conducted, medical waste can be incinerated, however waste is often disposed of through open burning. The capacity for waste-to-energy recovery in Addis is very low. In 2016, a total of 2,405,285 tonnes of medical and solid waste were consumed by incineration and open burning, and the resulting emissions from this were estimated to be 701,866 tCO_2e – 36% of emission from the waste sector.

Wastewater Treatment

Similar to solid waste management, wastewater management systems in Addis Ababa are affected by an increasing population. Currently, the city is mainly served by latrine systems with several small capacity centralized wastewater treatment plants. The accounting of Addis Ababa wastewater GHG emissions was based on the method provided in the GPC. N_2O emissions from domestic wastewater were estimated based on the city's population and protein consumption. Protein consumption activity data was collected from FAO national-level data for Ethiopia. Addis Ababa GHG emissions from waste are considered Scope 1 emissions as all Addis Ababa waste is treated or discharged within the city boundary. The GHG emissions from wastewater treatment in Addis Ababa account for 21% (404,447 tCO2e) of the total waste sector emissions. The share of emissions from residential wastewater was estimated to be 396,721 tCO_2e (98%), whereas industrial wastewater accounted 7,726 tCO_2e (2%). The industries that are responsible for generating wastewater were dairy factories, fish processing facilities, meat industries, plastic, pulp and paper manufacturers, and soap and starch factories.

Industrial Processes and Product Use (IPPU)

Emissions from non-energy related product use are characterized, assessed and reported as IPPU. Addis Ababa's sources have been identified from those included in Ethiopia's national GHG inventory. Emissions (CO_2, CH_4 and N_2O) are reported in Scope 1. Product use emissions in Addis Ababa largely arise from the use of lubricant and paraffin. As there is no city-specific data, national-level activity data was scaled down to Addis Ababa and the calculations applied were based on the method recommended in the GPC. Industrial emissions in 2016 (11,434 tCO_2e) were found to be slightly higher than in 2012 (10,514.5 tCO_2e). The rate of growth has slowed by 4% and CO_2 per unit of GDP has increased in most cases. The activity data for paraffin was based on the national import data, provided by the Ethiopian Revenues and

Customs Authority, as well as additional data taken from the ERCA Website. A ratio of 80% was used to scale down the national data to Addis Ababa. Since CH_4 and N_2O emissions are very small in comparison to CO_2, these can be neglected for the GHG calculation. The total consumption of paraffin was 770 TJ, contributing emissions of 11,300 tCO_2e. The total lubricant product use consumption in the city was 9 TJ and contributed 134 tCO_2e.

Agriculture, Forestry and Other Land Use (AFOLU)

AFOLU activities are divided into three categories: livestock, land, and aggregate and non-CO_2 emissions sources on land. GHGs from AFOLU consist of CH_4, N_2O and CO_2. GHG emissions were calculated based on the methods recommended in the GPC. Since all livestock activities are taking place within the city boundary, all the resulting GHG emissions are considered Scope 1 emissions.

GHG emissions from AFOLU are produced from biological activities linked to bacterial decomposition processes in cropland and grassland soils and in livestock digestive systems. Emissions include processes linked to enteric fermentation, manure management, application of fertilizers, manure left on pasture, manure applied to soils, cultivation of organic soils, crop residues decay, prescribed burning of savannahs and field burning of crop residues.

Emissions from enteric fermentation consist of CH_4, produced in digestive systems of ruminants, and to a lesser extent of non-ruminants. GHG emissions from manure management consist of CH_4 and N_2O from aerobic and anaerobic decomposition processes. Estimates include emissions by cattle, sheep, goats and poultry. Emissions from the AFOLU sector in Addis Ababa totaled 141,329 tCO_2e in 2016.

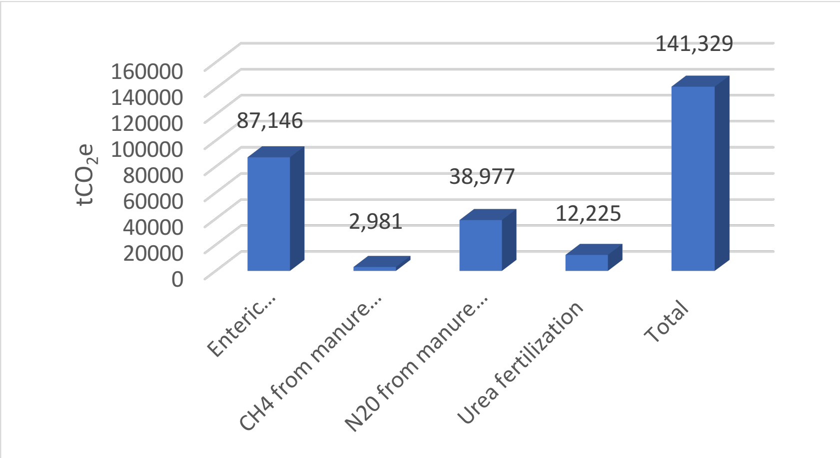


Figure 17: GHG emissions from AFOLU sectors in Addis Ababa

Livestock

CH_4 is produced by the digestive processes of livestock (enteric fermentation) and through management of their manure. N_2O is emitted from the manure management system. The number of livestock (dairy cattle, non-dairy cattle, sheep, goat and poultry) in Addis Ababa City was sourced from Addis Ababa Urban Agriculture Office.

In 2016, annual GHG emissions from enteric fermentation were 2,071 $MtCO_2e$, about 40% of total emissions from agriculture in the same year. Emissions of enteric fermentation were dominated by cattle, contributing 74% (55% non-dairy cattle; 19% dairy cattle), followed by buffaloes (11%), sheep (7%) and goats (5%). GHG emissions from manure management consist of CH_4 and N_2O were estimated to be 361 $MtCO_2e$ – approximately 7% of total emissions from agriculture in the same year.

Aggregate sources and non-CO_2 emission sources on land

Data on aggregate sources and non-CO_2 emission sources on land, including urea fertilizer consumption, was provided by the Addis Ababa urban agriculture office. The annual emissions from fertilizers were 12,225 tCO_2e, 9% of total emissions from AFOLU. AFOLU emissions represented 1% of Addis Ababa's total GHG emissions.

6. Conclusions and Recommendations

6.1. Conclusion

The preparation of the GHG emissions inventory is aimed at supporting the city's vision to become a resilient and sustainable city by 2030 which turn, contributes to the national Climate Resilience Green Economy Strategy (CRGE) goals and the Paris Agreement. The GPC Standard has been used together with the latest GHG data to take stock of the city's emissions. The emissions inventory report showcases the amount of emissions released into the atmosphere as result of different activities in the city such as transportation, energy use, and waste. The emissions from the transport sector are the highest, followed by emissions from waste sector and energy use in buildings respectively. The 2016 GHG inventory will be used to prepare the emission reduction targets for the city in the 2030, 2040 and 2050 - time horizons and this will be reflected in the climate action plan currently under development. Priority climate actions and emission reduction targets will be set for the BASIC level sectors presented in this report and this will be monitored over time, to ensure that the city transitions to a carbon-neutral and resilient city that delivers bespoke socio-economic and environmental benefits to the city residents.

Through the inventory preparation process, it has been observed that there are data gaps and issues with the quality of data used, but this will be resolved in future inventories to make sure that the process is thorough and takes into consideration the findings are recommendations presented in the GHG management plan prepared for the 2016 inventory.

6.2. Recommendations

i. **Improving the GHG inventory compilation process and management through strengthening institutional capacity**: GHG emissions inventory preparation needs to engage cross-sectoral institutions. It is essential to coordinate with these institutions to strengthen data quality. The availability and quality data were the main challenges in preparing the 2016 GHG emissions inventory. The data required in most sectors was partially available and this had an impact on the overall results and limited accuracy. The quality of activity data obtained for most sectors was low except for the aviation sector. Capacity building is necessary in relevant sectors/institutions to fill these data quality gaps for future emission inventories for the city.

ii. **Improved and coordinated communication**: Incorporating better communication channels and processes within relevant sectors that provide GHG data for the inventory will improve the stakeholders' engagement and exchange of data to improve the GHG data management and processes. This can be achieved by utilising existing communication channels or establishing a communication department/or dedicated staff solely to deliver on this and embed this in relevant sectors/departments. Useful information on who to engage is available in the Stakeholder Engagement Strategy developed for Addis.

iii. **Upgrading future GHG inventory to Basic + level of reporting:** The 2016 GHG inventory encompasses the BASIC level of reporting under the GPC Standard and covers the energy, transport, and waste sectors. However, in the coming years, the level of reporting will be upgraded to BASIC + to include IPPPU and AFOLU to provide a holistic overview of emissions sources in the city to ultimately develop comprehensive policy interventions that enhance optimal emission reductions. This will also ensure that the city undertakes holistic steps to address climate change while contributing to the overall resilience of the country.

iv. **Include the findings into climate action planning process (both nationally and city-wide)**: The results from the inventory will be used for climate action planning. AAEPGDC is working in collaboration with C40 Cities Climate Leadership Group to develop the city's first climate action plan (CAP) that is targeted to reducing GHG emissions by 2030 in the medium term and 2050 in the longer term in line with the Paris Agreement. This is the 2nd inventory for the city and provides a good foundation on key sectors for urgent mitigation action. The GHG inventory is critical in informing policy work on key relevant sectors on how to improve efficiency and reduce pollution in the transport sector, utilising energy efficiently in buildings and how to properly manage waste among other interventions.

v. **Comprehensive reporting and monitoring of GHG data**: This will be critical for future inventories in making sure that the data used in the climate action planning process is as detailed as possible to develop realistic emission reductions targets and ambition that can attract financing for feasible projects within the city and hence contribute to the nation's wider climate change goals.

ANNEXES

ANNEX I: Abbreviations

a) Abbreviations for Greenhouse Gases and Chemical Compounds

CO_2	Carbon dioxide
CH_4	Methane
N_2O	Nitrous oxide
HFCs	Hydrofluorocarbons
PFCs	Perfluorocarbons
NF_3	Nitrogen trifluoride
SF_6	Sulphur hexafluoride
CO	Carbon monoxide
NMVOC	Non-methane volatile organic compound
NOx	Nitrogen oxides (reported as nitrogen dioxide)
SO_2	Sulphur oxides (reported as sulphur dioxide)

b) Abbreviations for Technical Terms

GPC	Global Protocol for Community-Scale GHG Emission Inventories
IPCC	Intergovernmental Panel on Climate Change
C40	C40 Cities Climate Leadership Group
CIRIS	City Inventory Reporting and Information System
IPPU	Industrial Processes and Product Use
AFOLU	Agriculture, Forestry and Other Land Use
GHG	Greenhouse Gas
GWP	Global Warming Potential
AR2 / AR4 / AR5	2^{nd} / 4^{th}/ 5^{th} Assessment Report of the IPCC

ANNEX II: Activity Data, Data Sources and Emission Result

A1. Stationary Energy Activity Data, Data Sources and Emission Result

Scope	I.1 RESIDENTIAL BUILDINGS	Activity data		GHGs (metric tons CO2e)			Total tCO2e	CO2(b)	Source	Data Quality
	Activity	**Amount**	**Unit**	**CO2**	**CH4**	**N2O**				
1	Wood	675,964,800	kg	-	103,064	16,380	119,445	1,539,093	Central Statics Agency	L
1	Charcoal	136,292,744	kg	-	20,103	1,198	21,301	450,311	Central Statics Agency	L
1	Wood waste-Saw dust	316,268,372	kg	-	48,221	7,664	55,885	720,106	Central Statics Agency	L
1	Wood or wood waste-BLT (Bark, leave and Twigs	1,522,530,240	kg	-	232,140	36,895	269,035	3,466,624	Central Statics Agency	L
1	Municipal wastes (biomass fraction)	207,309,284	kg	-	20,072	-	20,072	-	Central Statics Agency	L
1	Kerosene	51,937,970	l (liter)	129,216	449	321	129,986	-	Central Statics Agency	L
1	Liquefied Petroleum Gas (LPG)	8,945,442	l (liter)	14,061	29	7	14,096	-	Central Statics Agency	L
2	Electricity	1,387,806,822	kWh	132	3	95	230	-	Ethiopia Electric Utility	M
	I.2 COMMERCIAL AND INSTITUTIONAL BUILDINGS AND FACILITIES									
1	Wood or wood waste	145,328,244	kg	-	22,158	3,522	25,680	330,896	Central Statics Agency	L
1	Liquefied Petroleum Gas (LPG)	2,236,360	l (liter)	3,515	7	2	3,524	-	Central Statics Agency	L
1	Diesel oil	8,819,820	l (liter)	25,157	85	61	25,302	-	Power Outages, Its Economic Cost and Firm Performance: Evidence From Ethiopia, 2018 (By Lamessa Tariku) https://ideas.repec.org/p/mil/wpdepa/2018-01.html	L
1	Motor gasoline (petrol)	9,692,110	l (liter)	23,401	84	60	23,545	-	<<	L
2	Electricity	784,990,369	kWh	75	2	54	130	-	Ethiopia Electric Utility	M
2	Electricity	13,571,091	kWh	1	0	1	2	-	Ethiopia Electric Utility	M
	I.3 MANUFACTURING INDUSTRIES AND CONSTRUCTION									
1	Residual fuel oil	17,385	ton	54,362	53	126	54,540	-	Ethiopia Petroleum Supply Enterprise	M
1	Residual fuel oil	16,995	ton	53,143	51	123	53,317	-	Ethiopia Petroleum Supply Enterprise	M
1	Diesel oil	1,417,760	l (liter)	4,082	13	195	4,290	-	Addis Ababa Driver & Vehicle Licensing & Control Authority	L
1	Diesel oil	23,995,242	l (liter)	68,442	69	165	68,676	-	Power Outages, Its Economic Cost, 2018 (By Lamessa Tariku)	L
2	Electricity	1,051,624,184	kWh	100	3	72	174	-	Ethiopia Electric Utility	L
	I.4 ENERGY INDUSTRIES									
1	Wood or wood waste	1,272,773,871	kg	-	194,060	30,843	224,902	2,897,958	Central Statics Agency	L
	I.5 AGRICULTURE, FORESTRY AND FISHING ACTIVITIES									
1	Diesel oil	681,120	l (liter)	1,961	6	94	2,061	-	Addis Ababa Driver & Vehicle Licensing & Control Authority	L

A2. Transport Activity Data, Data Sources and Emission Result

A.2.1. Road Transport

S/N	Vehicle Categories	Vehicles Type	AADT By Vehicle Categories	Vec Stock	VKT/Year	Ave.Fuel Economy (km/l)		Fuel Consumption (liter)				Emission per ton			
						Gasoline	Diesel	Scope 1		Scope 3		Scope 1		Scope 3	
								Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel
1	Cars	Ambulance	2,829	130	22,043	12	11	118,474	129,244	926	1,010	316	391	2	3
2		Automobile		125,783	22,043	12		229,261,720		1,791,169		611,260		4,776	
3	Land rovers	Field Vehicle	3,969	32,683	15,261	11	10	22,331,172	24,564,290	340,431	374,474	59,540	74,332	908	1,133
4		Dual Purpose Vehicle		28,568	22,043	11	10	27,983,869	30,782,256	639,968	703,965	74,611	93,148	1,706	2,130
5	Small Buses	Bus(> 11 Seats)	5,780	5,214	109,361	12		33,068,222		14,449,133		88,167		38,524	
				5,214	109,361		11		36,074,423	-	15,762,691		109,162		47,698
6	Large Buses	Bus(< 12 Seats)	2,513	17,755	83,426		6		228,260,412	-	18,611,027		690,724		56,318
7	Small Track	Dry Cargo(<=10 Quintals)	3,227	23,128	50,869		5		219,228,412	-	16,071,234		663,393		48,632
8	Medium and Heavy Track	Dry Cargo(>10 Quintals)	9,189	67,334	84,782		5		1,062,994,987	-	78,747,251		3,216,659		238,292
9		Liquid Cargo		3,772	70,539		5		(14,238,519)	-	67,453,141		(43,086)		204,115
10	Track and Trail	Trailer	4,631	16,808	84,782		5		249,762,941	-	35,240,230		755,791		106,638
11		Gotach		3,181	84,782		5		47,268,915	-	6,669,394		143,037		20,182
13	Motor bicycle	Motor bicycle	-	13,980	10,174	33		4,310,076		-		11,492			
14		Three-wheel dry load		7	25,435	20		8,902		-		24			
15		Three-wheel public load		212	25,435	20		269,611		-		719			
16	Others	Others	4,017	6,270	56,570	8	7	15,057,384	16,989,996	7,110,984	8,023,678	40,146	51,412	18,959	24,280
Data Source	• The Categories of the Vehicles from Ethiopian Road Authority (ERA) Traffic Count Data and Addis Ababa Driver & Vehicle Licensing & Control Authority • Vehicle count from five gates of Addis Ababa - source: Ethiopia Road Authority • National Average VKT and fuel economy from National Transport GHG Emission Inventory in 2018, Ministry of Transport AADT= Annual Average Daily Travel							Calculation Result							

A.2.2. Aviation

Scope	Waste Activity	Activity data Amount	Unit	GHGs (metric tons CO2e)			Total tCO2e	CO2(b)	Source	Data Quality
				CO2	CH4	N2O				
1	Jet gasoline-international flight	158,095,992	liter	412,789	67,191	3,250,770	3,730,749	-	Ethiopian Airline/ Ethiopian Civil Aviation	H
1	Jet gasoline-domestic flight	3,284,215	liter	8,575	1,396	67,530	77,501	-	Ethiopian Airline/ Ethiopian Civil Aviation	H

A.2.3. Railway

Scope	Waste	Activity data	Unit	GHGs (metric tons CO2e)	Total tCO2e	CO2(b)	Source	Data Quality

	Activity	Amount		CO2	CH4	N2O				
1	Electricity consumption	16,200,000	Kwh	2	0	1	3	-	Addis Ababa Light Railway Transit Project Office	H

A3. Waste Activity Data, Data Sources and Emission Result

	Waste	Activity data	Unit	GHGs (metric tons CO2e)			Total			Data
Scope	Activity	Amount		CO2	CH4	N2O	tCO2e	CO2(b)	Source	Quality
1	Municipal solid waste	697,697	tone		836,120		836,120	91,973	Addis Ababa Solid Waste Administration Agency	L
1	Composting- all organic waste	23,064	tone		2,306	1,650	3,956	NA	Addis Ababa Solid Waste Administration Agency	L
1	Open burning of waste	24,729	tone	2,465		1,105	3,570	NA	Evaluating the Management Practice of Unintentionally Produced Persistent Organic Pollutants (Dioxin and Furan): The Case of Addis Ababa, Ethiopia	L
1	Waste incineration	2,380,556	tone	698,296			698,296	NA	>>	L
1	Domestic wastewater	3,353,000	population		358,265	38,456	396,721	NA	Ministry of Trade and Industry	L
1	Industrial wastewater	50,535	tone		7,726		7,726	NA	Ministry of Trade and Industry	L

A4. IPPU Activity Data, Data Sources and Emission Result

	IPPU	Activity data	Unit	GHGs (metric tons CO2e)			Total			
Scope	Activity	Amount		CO2	CH4	N2O	tCO2e	CO2(b)	Source	Data Quality
1	Lubricant	9	TJ	134	-	-	134	-	National import data from Ethiopia Revenue and Custom Authority	L
1	Paraffin	770	TJ	11,300	-	-	11,300	-	National import data from Ethiopia Revenue and Custom Authority	L

A5. AFOLU Activity Data, Data Sources and Emission Result

	AFOLU	Activity data	Unit	GHGs (metric tons CO2e)			Total			
Scope	Activity	Amount		CO2	CH4	N2O	tCO2e	CO2(b)	Source	Data Quality
1	Cattle Enteric fermentation	104,482	head		80,974		80,974	-		
1	Sheep enteric fermentation	30,190	head		3,774		3,774	-		
1	Goats enteric fermentation	19,183	head		2,398		2,398	-		
1	Cattle manure mangement_CH4	104,482	head		2,612		2,612	-		
1	Sheep Manure management_CH4	30,190	head		113		113	-		
1	Goats Manure mangement_CH4	19,183	head		82		82	-		
1	Poultry manure mangement_CH4	348,418	head		174		174	-		
1	Manure management Other Cattle Pasture, range, and paddock_N2O	104,482	head			13,625	13,625	-		
1	Manure management Other Cattle Solid Storage /Dry lot _N2O	104,482	head			17,518	17,518	-		
1	Manure management Sheep Pasture, range, and paddock_N2O	30,190	head			2,705	2,705	-		
1	Manure management Sheep Solid Storage /Dry lot _N2O	30,190	head			676	676	-		
1	Manure management Goats Pasture, range, and paddock_N2O	19,183	head			2,156	2,156	-		
1	Manure management Goats Solid Storage /Dry lot _N2O	19,183	head			539	539	-		
1	Manure management Poultry Pasture, range, and paddock_N2O	348,418	head			1,758	1,758	-	Addis Ababa Urban Agriculture Office	L

A6. Summary of methods and assumptions

Source	Method	Assumption
Stationary Energy		
Biomass energy	Activity data x emission factor	The Activity data is the amount of energy consumption per year in different type of buildings. The emission factor is a default factor form IPCC. The emission result is the multiplication of activity data and emission factor. **Wood/ wood waste**: From the 1.68 m3 per HH wood consumption converted into kg using 600 kg/m3 eucalyptus tree wood density, Average city HH size is 5.. For BLT, 4.8 m3 changed to kg using the density of eucalyptus tree bark/branch 473 kg/m3. **LPG**: The total sale value from two big dealers of LPG is found and together they cover the demand for LPG in Addis Ababa of 85%, kg to lite is changed through LPG density which is 580 kg/m3, **Residual Fuel**: From the national petroleum supply we got the total light and heavy furnace oil purchase, and then the total medium and large scale industry share of Addis Ababa 45 %. Kerosene is used at household level and multiplication of per capita consumption and emission factor. **Apportioning to building types**: The residential, commercial and the energy industries apportioned with the assumption that 32.28 %, 6.94 % and 60.78 % fuelwood is consumed at the commercial and energy industries per Biomass strategy of Ethiopia. **The diesel and gasoline consumption** are as result of i) heavy duty vehicle that used in agriculture and manufacture which accounted based on fuel consumption /hour /day and annual operation days and ii) generator back up as result of electricity interruption estimated using the average electricity interruption and kwh required to fill the power outrage is estimated
Kerosene	Activity data x emission factor	
Electricity	Activity data x emission factor	
LPG	Activity data x emission factor	
Diesel Oil-During electricity interruption	Activity data x emission factor	
Gasoline Oil-During electricity interruption	Activity data x emission factor	
Residual fuel	Activity data x emission factor	
Transport		
On-Road		
Diesel	Induced activity method. Activity data x emission factor	The Activity data is the amount of energy consumption per year by vehicles categories. The emission factor is a defuel factor form IPCC. Therefore, the emission is the multiplication of activity data and emission factor. To calculate the fuel consumption and emission from scope 1 and 3. The following variables are used -fuel economy, vehicle kilometer travel, traffic count etc
Gasoline	Induced activity method. Activity data x emission factor	
Aviation		
Jet fuel	Fuel sale approach. Activity data x emission factor	The Activity data is the amount of fuel consumed per year by airplanes. The emission factor is a default factor form IPCC. Therefore, the emission is the multiplication of activity data and emission factor. Apportioning of the domestic and international flight to the city were undertaken through Origin apportioning method. For international flight, origin method is the number of flight originated from Addis Ababa to outside Ethiopia cities/towns, thus this used to apportion the flight transit data and fuel consumption for international flight. For domestic flight, the origin method is the number of flight originated from Addis Ababa to other Ethiopian cities/towns which used to understand the flight transit data and apportion to Addis Ababa based on the city urban population shared
Railway		
Electricity	Induced activity method. Activity data x emission factor	The Activity data is the amount of electricity consumption per year by building types. The emission factor is a default factor form IPCC. Monthly electric consumption bills are converted into annual consumption
Waste		
Municipal Solid Waste	Methane commitment approach, using CIRIS calculator	CIRIS solid waste calculator used for methane commitment method. Waste composition data available for Addis Ababa. Tonnage is from 2016. No landfill gas capture or energy, unmanaged site, >5m deep. Assumed all organic waste is food waste and the waste composition of board is assumed to be wood.
Composting-all organic waste	Using CIRIS calculator	CIRIS biological treatment calculator used. Assumed 5% of organic waste fraction of total solid waste is composted - household composting and some associations. Used IPCC default factors from CIRIS calculator. Assumed wet waste.
Open burning of waste/ incineration	Using CIRIS calculator	Stated total tonnage of waste incinerated per year in hospitals and kg of waste per patient and number of the total patient in the accounting year
Domestic wastewater	Using CIRIS calculator	Calculated using CIRIS wastewater calculator. Based on population with city-specific treatment pathway data. 58083m3 / year BOD removed as sludge - converted to kg for calculation using assumption: 1 cubic meter of Sewage, sludge weighs 721 kilograms [kg] https://www.aqua-calc.com/calculate/volume-to-weight. MCF specified as 0.5 for fast-flowing sewer. Default value in CIRIS for Ethiopia protein consumption for N2O emissions is used
Industrial wastewater	Using CIRIS calculator	Calculated using CIRIS wastewater calculator for industrial wastewater, based on tonne-product data of key industries scaled to Addis based on national population and or GDP shares
IPPU		
Lubricant	Activity data x emission factor	The Activity data is the amount of lubricant consumption per year. The emission factor is a default factor form IPCC. The Activity data is from Ethiopia Revenue and Custom Authority website. The activity data downscale to the city level assuming 60% of national vehicle registrations in the city. CH4 and N2O emissions are very small in comparison to CO2, and neglected for the greenhouse gas calculation.
Paraffin	Activity data x emission factor	The Activity data is the amount of paraffin consumption per year. The emission factor is a default factor form IPCC. The Activity data is from Ethiopia Revenue and Custom Authority website. The activity data downscale to the city level assuming 80% consumed in the city. CH4 and N2O emissions are very small in comparison to CO2, and neglected for the greenhouse gas calculation.
AFOLU		
Enteric fermentation	Activity data x emission factor	The activity data is the numbers of livestock (head) data has been multiplied by IPCC 2006 default values for livestock types.
Manure management	Activity data x emission factor	Manure management N2O are estimated following IPCC 2006 Guidelines, calculating an implied emission factor for each livestock category and manure management regime. Dung used as fuel has been excluded. All IPCC defaults are used except for proportions of manure management systems utilized taken from the Ethiopia 2nd National Communication.
Urea fertilizer application	Activity data x emission factor	Activity data is urea fertilizer applied to agricultural land and default emission factor from IPCC 2006 guideline

A7. Detailed overview of reasons for changes between years

Consider using a table such as this to provide a summary of the reasons for changes in emissions in sub-sectors.

Table A3.1: Analysis of changes in emissions subsectors

Source	GHG Emission		Change between current year (2016) base year (2012)	Reason
	2012	2016		
Stationary Energy				
Biomass energy	205,816	736,320	Increased by 530,504	Increased energy demand in the household and commercial institutions
Kerosene	1,277,180	129,986	Decreased by 1,147,194	Cheap electricity together with availability of technologies of household electricity appliances
Electricity	Not estimated	537	Not Applicable	NA
LPG	18,139	17,621	Decreased by 518	Cheap electricity together with availability of technologies of household electricity appliances
Diesel Oil-During electricity interruption	Not estimated	100,330	Not Applicable	NA
Gasoline Oil-During electricity interruption	Not estimated	23,545	Not Applicable	NA
Residual fuel	209,452	107,857	Decreased by 101,595	The possible reason for the change is the improving the energy efficiency of the industries
Transport				
On-Road				
Fuel consumption (diesel and gasoline	1,412,432	7,455,535	Increased by 6,043,103	Increase the number of vehicles in the city and increase per capita travel
Aviation				
International Aviation Trips	823,668	3,730,749	Increased by 2,907,081	Increased international travel demand and the quality of the data source
Domestic Aviation Trips	37,038	77,501	Increased by 40, 463	Increased domestic travel demand and the quality of the data source
Railway				
Electricity	Not estimated		Not Applicable	NA
Waste				
Municipal Solid Waste	315,692	836,120	Increased by 520,428	Increase in population and GDP
Composting-all organic waste	Not estimated	3,956	Not Applicable	NA
Open burning /incineration waste	Not estimated	701,866	Not Applicable	NA
Domestic wastewater	332,206	396,721	Increased by 64,515	Increase in population and GDP
Industrial wastewater	Not estimated	7,726	Not Applicable	NA
IPPU				
Lubricant	1,723	134	Decreased by 1,589	The possible in the consumption is the improved lubricant management in the transport sector
Paraffin	8,792	11,300	Increased by 2,508	The possible Increase in the consumption and production of cosmetics
AFOLU				
Enteric fermentation	227,844	87,145	Decreased by 140,699	Decrease the number of livestock in the city
Manure management	18,698	41,958	Increased by 23, 260	Improve the parameter used in the calculation
Urea fertilizer application	Not estimated	12,225	Not Applicable	NA

A8. GHG Inventory Improvements

Source	Improvement
Stationary Energy	
Biomass energy	Strengthen the data quality by collecting data of the energy consumption by buildings and energy types. These can be done through conducting survey in relation to central statistics agency activities or by including the activities in yearly plan and report in the relevant institutions in the city.
Kerosene	
Electricity	
LPG	
Diesel Oil-During electricity interruption	
Gasoline Oil-During electricity interruption	
Residual fuel	
Transport	
On-Road	
Diesel	Collect the data relevant to emission calculation in the existing annual vehicle inspection program. By which the Addis Ababa transport bureau can collect the data such as fuel economy, annual kilometer travel, vehicle age etc.
Gasoline	
Aviation	
Jet fuel	Strengthen the data quality by tracking the air plane fuel consumption by private and public aviation activities
Railway	
Electricity	Document electricity bill
Waste	
Municipal Solid Waste	There is a data gaps in the amount of waste converted in to biological treatment, open burning and incineration. The city solid waste management agency should work with the sub-city level offices to gather this information as part of the annual operational plan. Similarly, the wastewater data should also be collected in the annual operational plan by Addis Ababa Water and Sewerage Authority or relevant city authority
Composting-all organic waste	
Open burning of waste/incineration	
Domestic wastewater	
Industrial wastewater	
IPPU	
Lubricant	Making available the industrial product consumption data at the city level and industrial process emission like emission from glass factories by relevant institutions
Paraffin	
AFOLU	
Enteric fermentation	Strengthen the quality data that enables to have an accurate number of livestock, feeding and manure management and incorporate land use change in the future inventories
Manure management	

A9. Global Warming Potentials

GWPs used in the calculation of emissions

Table A 9.1 Global warming potentials (GWP) used in calculations, adapted from IPCC 2006 Guidelines.

Industrial designation or common name	Chemical formula	Lifetime (years)	Radiative efficiency ($W\ m^{-2}\ ppb^{-1}$)	Global warming potential for given time horizon (100 years)
Carbon dioxide	CO_2		$1.4x10^{-5}$	1
Methane	CH_4	12	$3.7x10^{-4}$	25

Nitrous oxide	N_2O	114	$3.03x10^{-3}$	298

A10. GPC Definitions

A10.1. Sector Definitions

Sectors and sub-sectors	Definition
Stationary energy	GHG emissions come from fuel combustion, as well as fugitive emissions released in the process of generating, delivering, and consuming useful forms of energy (such as electricity or heat).
Residential buildings	All emissions from energy use in households
Commercial buildings	All emissions from energy use in commercial buildings and facilities
Institutional buildings	All emissions from energy use in public buildings such as schools, hospitals, government offices, highway street lighting, and other public facilities
Manufacturing industries and construction	All emissions from energy use in industrial facilities and construction activities, except those included in energy industries sub-sector. This also includes combustion for the generation of electricity and heat for own use in these industries
Energy industries	All emissions from energy production and use in energy industries
Energy generation supplied to the grid	All emissions from the generation of energy for grid-distributed electricity, steam, heat and cooling
Agriculture, forestry, and fishing activities	All emissions from energy use in agriculture, forestry, and fishing activities
Non-specified sources	All remaining emissions from facilities producing or consuming energy not specified elsewhere
Fugitive emissions from mining, processing, storage, and transportation of coal	Includes all intentional and unintentional emissions from the extraction, processing, storage and transport of fuel in the city
Fugitive emissions from oil and natural gas systems	Fugitive emissions from all oil and natural gas activities occurring in the city. The primary sources of these emissions may include fugitive equipment leaks, evaporation losses, venting, flaring and accidental releases.
Transportation	City transportation systems are designed to move people and goods within and beyond city borders. Transport vehicles and mobile equipment or machinery produce GHG emissions directly by combusting fuel or indirectly by consuming grid-delivered electricity.
On-road	On-road vehicles are designed for transporting people, property or material on common or public roads, thoroughfares, or highways. This category includes vehicles such as buses, cars, taxis, trucks, motorcycles, on-road waste collection and transportation vehicles (e.g. compactor trucks), etc.
Railways	Railways typically use energy through combustion of diesel fuels or electricity. Railways can be divided into four sub-categories: urban railway subway systems

	including trams, regional commuter rail national rail and international rail. Each can be further classified as passenger or freight.
Waterborne navigation	Water transportation includes ships, ferries, and other boats operating within the city boundary, as well as marine-vessels whose journeys originate or end at ports within the city's boundary but travel to destinations outside of the city.
Aviation	Civil aviation, or air travel, includes emissions from airborne trips occurring within the geographic boundary (e.g., helicopters operating within the city) and emissions from flights departing airports that serve the city
Off-road	Off-road vehicles are those designed or adapted for travel on unpaved terrain. This category typically includes airport ground support equipment, all-terrain vehicles, landscaping and construction equipment, bulldozers, forklifts, snowmobiles etc.
Waste	Waste disposal and treatment produces GHG emissions through aerobic or anaerobic decomposition, or incineration.
Solid waste generated in the city	Solid waste may be disposed of at managed sites (e.g., sanitary landfill and managed dumps), and at unmanaged disposal sites (e.g., open dumps, including above-ground piles, holes in the ground, and dumping into natural features, such as ravines)
Biological waste generated in the city	The biological treatment of waste refers to composting and anaerobic digestion of organic waste, such as food waste, garden and park waste, sludge, and other organic waste sources.
Incinerated and burned waste generated in the city	Incineration is a controlled, industrial process, often with energy recovery where inputs and emissions can be measured and data is often available. By contrast, open burning is an uncontrolled, often illicit process with different emissions and can typically only be estimated based on collection rates.
Wastewater generated in the city	Wastewater can be treated aerobically (in presence of oxygen) or anaerobically (in absence of oxygen). Wastewater can generally be categorized as domestic wastewater or industrial wastewater, and cities must report emissions from both.
Industrial processes and product use	GHG emissions resulting from non-energy related industrial activities and product uses. All GHG emissions occurring from industrial processes, product use, and non-energy uses of fossil fuel, shall be reported under IPPU.
Industrial processes	GHG emissions are produced from a wide variety of industrial activities. The main emission sources are releases from industrial processes that chemically or physically transform materials. Note, if fuels are combusted for energy use, the emission shall be reported under Stationary Energy.
Product use	Products such as refrigerants, foams or aerosol cans can release potent GHG emissions
Agriculture, forestry, and fishing activities	GHG emissions are produced through a variety of pathways, including land-use change that alter the composition of the soil, methane produced in the digestive processes of livestock, and nutrient management for agricultural purposes.
Livestock	Livestock production emits CH4 through enteric fermentation, and both CH4 and N2O through management of their manure.
Land	Emissions and removals of CO2 are based on changes in ecosystem C stocks and are estimated for each land-use category. C stocks consist of above-ground and below-ground biomass, dead organic matter, and soil organic matter.
Other agriculture	Other sources of GHG emissions from land include rice cultivation, fertilizer use, liming, and urea application.

Other scope 3	Cities may optionally report other scope 3 emissions, such as GHG emissions embodied in fuels, water, food and construction materials.

A10.2. Scope Definitions

Scope	Definition
Scope 1	GHG emissions from sources located within the city boundary.
Scope 2	GHG emissions occurring as a consequence of the use of grid-supplied electricity, heat, steam and/or cooling within the city boundary.
Scope 3	All other GHG emissions that occur outside the city boundary as a result of activities taking places within the city boundary.