



# Lesotho's 4th National Greenhouse Gas Inventory: 2011 - 2017



## National Inventory Report





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## Acronyms and Abbreviations

<b>AC</b>	Air Conditioning
<b>AFOLU</b>	Agriculture, Forestry and Other Land Use
<b>AMESD</b>	African Monitoring of the Environment for Sustainable Development
<b>BOS</b>	Bureau of Statistics
<b>BUR</b>	Biennial Update Reports
<b>CH<sub>4</sub></b>	Methane
<b>CO</b>	Carbon Monoxide
<b>CO<sub>2</sub></b>	Carbon Dioxide
<b>CO<sub>2e</sub></b>	CO <sub>2</sub> -equivalent
<b>DOE</b>	Department of Energy
<b>DOF</b>	Department of Forestry
<b>EF</b>	Emission factor
<b>ERM</b>	Environmental Resources Management
<b>EU</b>	European Union
<b>FAO</b>	Food and Agriculture Organization
<b>FOLU</b>	Land use Change and Forestry Sector,
<b>FRA</b>	Forest Resource Assessment
<b>GDP</b>	Gross Domestic Product
<b>Gg</b>	Gigagram
<b>GHG</b>	Greenhouse gas
<b>GWP</b>	Global Warming Potential
<b>H<sub>2</sub>O</b>	Water
<b>HFCs</b>	Hydrofluorocarbons
<b>IEA</b>	International Energy Agency
<b>IPCC</b>	Intergovernmental Panel on Climate Change
<b>IPPU</b>	Industrial Processes and Product Use
<b>ISWMS</b>	Integrated Solid Waste Management System
<b>LDF</b>	Lesotho Defence Force
<b>LHWP</b>	Lesotho Highlands Water Project
<b>LMS</b>	Lesotho Meteorological Services

<b>LNDC</b>	Lesotho National Development Corporation
<b>LPG</b>	Liquid Petroleum Gas
<b>LRA</b>	Lesotho Revenue Authority
<b>MAF</b>	Mission Aviation Fellowship
<b>MAFS</b>	Ministry of Food and Agriculture
<b>MCC</b>	Maseru City Council
<b>MIA</b>	Moshoeshoe International Airport
<b>MPV</b>	Multi-Purpose Vehicle
<b>MSD</b>	Municipal Solid Waste
<b>MSWD</b>	Municipal Solid Waste Dump
<b>N</b>	Nitrogen
<b>N<sub>2</sub>O</b>	Nitrous Oxide
<b>NCV</b>	Net Calorific Values
<b>Nex</b>	Nitrogen excretion rate
<b>NH<sub>3</sub></b>	Ammonia
<b>NMVOCs</b>	Non-methane Volatile Organic Compounds
<b>NO<sub>x</sub></b>	Nitrogen oxides (nitric oxide (NO) and nitrogen dioxide (NO <sub>2</sub> ))
<b>ODS</b>	Ozone Depleting Substances
<b>PFCs</b>	Perfluorocarbons
<b>QA</b>	Quality Assurance
<b>QC</b>	Quality Control
<b>SACU</b>	Southern Africa Customs Union
<b>SOC</b>	State-owned Company
<b>SWDS</b>	Solid Waste Disposal Sites
<b>TAM</b>	Typical Animal Mass
<b>TJ</b>	Terajoules
<b>TL</b>	Team Lead
<b>UNFCCC</b>	United Nations Framework Convention on Climate Change
<b>USGS</b>	U.S. Geological Survey
<b>WASCO</b>	Water and Sewerage Company
<b>WMO</b>	World Meteorological Organisation



## *Definitions of commonly-used terms*

### **Aerobic**

Processes occurring in the absence of oxygen.

### **Anaerobic**

Processes occurring in the absence of oxygen, i.e. conditions conducive to the conversion of organic carbon into CH<sub>4</sub> rather than CO<sub>2</sub>.

### **CO<sub>2</sub>-equivalent (CO<sub>2</sub>e) emission**

The amount of CO<sub>2</sub> emissions that would cause the same time-integrated irradiative forcing, over a given time horizon. The CO<sub>2</sub>e emission is a standard metric for comparing emissions of different GHGs (IPCC, 2013).

### **Crop residue**

Materials left in an agricultural field after the crop has been harvested.

### **Emission factor**

Factor that defines that rate at which a GHG is emitted.

### **Global Warming Potential (GWP)**

An indicator that reflects the relative effect of a GHG in terms of climate change considering a fixed period, compared with the same mass of CO<sub>2</sub>.

### **Key category**

A key category is one that is prioritised within the national inventory system because its estimate has a significant influence on a country's total inventory of greenhouse gases in terms of the absolute level of emissions and removals, the trend in emissions and removals, or uncertainty in emissions or removals. Whenever the term key category is used, it includes both source and sink categories.

### **Manure N**

Nitrogen in manure.

### **Methane conversion factor**

The percentage of the manure's maximum CH<sub>4</sub> producing capacity (Bo) that is achieved during manure management.

### **Synthetic N**

Nitrogen in the form of manufactured fertilizers, such as ammonium nitrate

## PREFACE

This report is Lesotho's 4<sup>th</sup> National GHG Inventory report, and it contains the country's national GHG inventories for the years 2011 to 2017. It has been compiled for Lesotho Meteorological Services (LMS). It has been prepared and compiled by Environmental Resources Management (ERM) based on data collected and calculated by LMS and various Lesotho departments and institutions. This inventory report was compiled based on Intergovernmental Panel on Climate Change (IPCC) 2006 Guidelines for National Greenhouse Gas Inventories.

## ACKNOWLEDGEMENTS

Numerous institutions and national departments from Lesotho contributed to this 4<sup>th</sup> GHG National Inventory Report for Lesotho by contributing data, information and their time. Thank you to the LMS GHG team for co-ordinating, communication and liaising with all of the departments and institutions in Lesotho. We really appreciate every form of involvement from each and every person in the compilation of this inventory.

Details of the organizations and team members that were involved in this inventory are presented in the next section under authors and contributors.

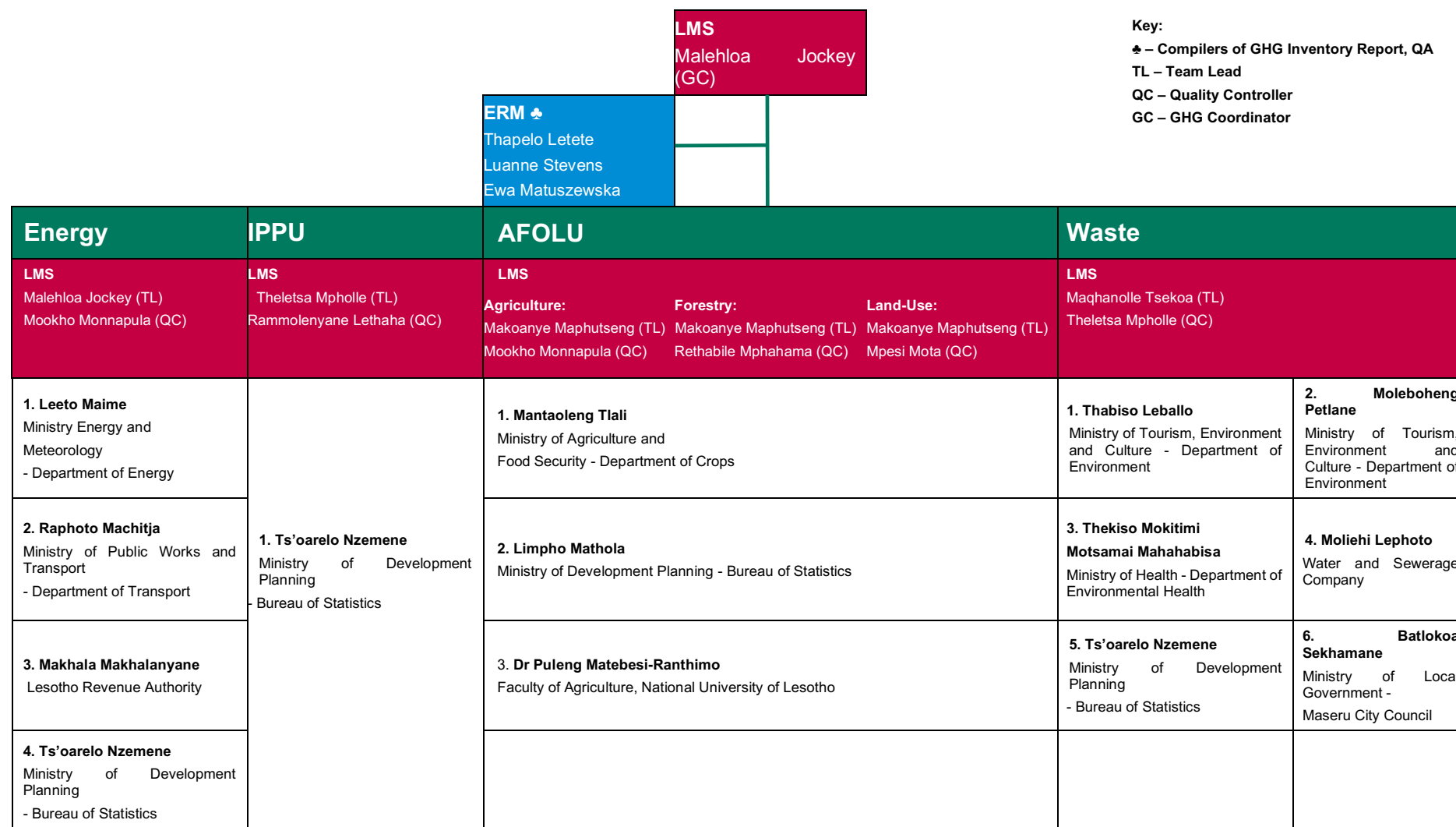
## RECOMMENDATION CITATION



## AUTHORS AND CONTRIBUTORS

Below is the organogram for the inventory and the list of all the individuals that were involved in the compilation of the 4<sup>th</sup> National GHG inventory.

**Figure A-0-1 Organogram of contributors**



## UNITS AND FACTORS

Below is a summary of the units and factors that were utilized in this report.

**Table A-0-1 Units used**

Multiplication factor	Abbreviation	Prefix	Symbol
1 000 000 000	10 <sup>9</sup>	Giga	G
1 000 000	10 <sup>6</sup>	Mega	M
1 000	10 <sup>3</sup>	Kilo	K
100	10 <sup>2</sup>	Hector	H

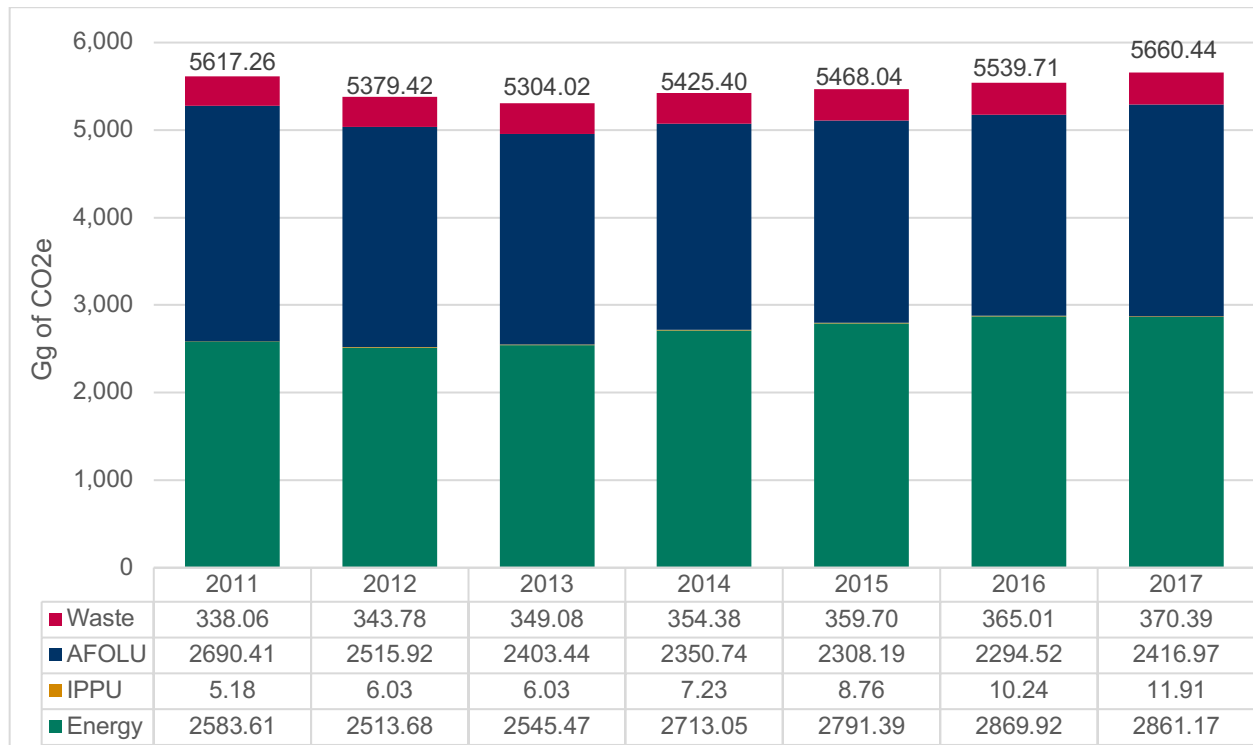
**Table A-0-2 conversion factors used**

Unit	Equivalence
1 tonne (t)	1 Megagram (Mg)
1 Kilotonne	1 Gigagram (Gg)
1 Megatonne	1 Teragram (Tg)

**Table A-0-3 Global Warming Potentials (GWP) (Solomon, et al., 2007)**

Greenhouse Gas	Chemical Formula	100-year GWP
Carbon Dioxide	CO <sub>2</sub>	1
Methane	CH <sub>4</sub>	21
Nitrous Oxide	N <sub>2</sub> O	310
HFC – 32	CH <sub>2</sub> F <sub>2</sub>	650
HFC – 125	CHF <sub>2</sub> CF <sub>3</sub>	2,800
HFC – 134a	CH <sub>2</sub> FCF <sub>3</sub>	1,300
HFC – 143a	CF <sub>3</sub> CH <sub>3</sub>	3,800

## EXECUTIVE SUMMARY





## 1. INTRODUCTION

This chapter presents the context to climate change and GHG inventories in Lesotho, as well as a concise country background.

### 1.1 Climate Change and GHG Inventories

Evidence of global climate change due to increase in the amount of greenhouse gases that are emitted into the atmosphere has been growing over the years. The annual average global temperature anomaly for the year 2017 (relative to 1951-1980 average temperatures) shows a change of 0.9°C in global surface temperatures.

In 1992 in order to battle climate change the United Nations Framework Convention on Climate Change (UNFCCC) was adopted as a framework for international cooperation for climate change response. The idea was to limit average global temperature increases, the resulting climate change, and their impacts ([www.unfccc.int](http://www.unfccc.int)). The UNFCCC “sets non-binding limits on greenhouse gas emissions for individual countries and contains no enforcement mechanisms. Instead, the framework outlines how specific international treaties (called “protocols” or “Agreements”) may be negotiated to specify further action towards the objective of the UNFCCC”. In order to assess the progress of the Parties in combating climate change, the Convention requires the regular submission of inventories of greenhouse gas emissions not controlled under the Montreal Protocol and reductions by sinks from Parties, known as National GHG Inventories

GHG inventories are also critical in tracking progress in implementation or attainment of Nationally-Determined Contributions submitted under the 2015 Paris Agreement.

### 1.2 Climate Change and Lesotho

Lesotho is one of the countries that are very susceptible to the negative impacts of climate change, and has already, in recent years, been affected by climate change impacts include storms, droughts and floods and an increase in the incidences of natural disasters. Precipitation has become unpredictable leading to droughts and dangerous farming conditions. Exacerbated by climate change, farming in Lesotho is in a fixed decline and the below aspects are on the increase:

- Depletion of the country’s natural resources;
- Food insecurity;
- Loss of biodiversity;
- Human, animal as well as crop diseases, and
- Soil loss, land and environmental degradation. (Lesotho’s National Climate Change Policy, 2017)

### 1.3 Lesotho’s National GHG inventories

Lesotho has submitted its initial, second and third national GHG inventories under the UNFCCC as part of the country’s National Communications.

Lesotho’s 1<sup>st</sup> National GHG inventory was compiled in 2000 for the year 1994, while the 2<sup>nd</sup> National GHG inventory was undertaken for the year 2000 and was published in 2013. Both inventories were based on the revised 1996 IPCC guidelines. Lesotho’s 3<sup>rd</sup> National GHG inventory was published in 2018, covering the years 2005 to 2010. The third inventory was based on the 2006 IPCC guidelines.

This report is Lesotho's 4<sup>th</sup> National GHG inventory and it is covering the years 2011 to 2017. It has been compiled using the 2006 IPCC guidelines.

Chapter 3 of this report presents the trends in Lesotho's National GHG emissions from 1994 to 2017, based on these published GHG inventory reports.

## 1.4 Country Background

### 1.4.1 Government structure

In Lesotho the government is a constitutional monarchy with its capital in Maseru. It is a hereditary monarchy and it's a living symbol of national unity with no executive legislative powers. The king is the executive branch and the head of state. His Majesty King Letsie III has occupied this position since 1996.

In January 1993 Lesotho became a democracy and its constitution was adopted on 2<sup>nd</sup> April 1993. The country is divided into ten administrative districts. The legal system is based on Roman Dutch law and the English common law. The judicial branch is the high court, with a chief justice that is appointed by the monarch. The legislative branch is made up of a two-tier parliament, with a senate that is selected by the ruling party and an assembly chosen by popular vote.

The below photo (Figure 1-1) is of the parliament building that is located in the capital Maseru. The parliament building is located on Mpilo hill.

**Figure 1-1 Photo of Lesotho's parliament building in Maseru**



*Photo taken by Ewa Matuszewska, ERM, 2019.*

### 1.4.2 Population profile

The population in Lesotho has risen from around 851 590 people in 1960 to 2 007 201 people in 2016 (Bureau of Statistics, 2018). In 2016 women made up 51.1% of the total population while men made up 48.9%. The majority of the population lies within the 0 – 34 age group. The average household size has declined from 5 people per household in 1976 to 3.7 people per household in 2016.

The 2016 Population and Housing Survey Age Specific Fertility Rates (ASFR) curve indicates that most females were giving birth at the age of 25 to 29 years and females of child bearing ages decrease with an increase in age. The HIV/AIDS prevalence rate in Lesotho is higher than the global average and more than half of its population lives below the poverty line. Infant mortality rate in Lesotho has improved significantly over the last two decades from 91 deaths per 1000 births in 2004 to 53 deaths per 1000 births in 2016.

### Figure 1-2 Map of Lesotho



Lesotho is unique in that it has all its land lying at altitudes in excess of 1 500m above sea-level and is known as the land of mountains. Lesotho has the highest mountain in Southern Africa at 3 482m (Thabana-Ntlenyana). Despite being landlocked by South Africa, Lesotho has great rail, air, and road links to all its main commercial centres (Lesotho government, 2019 ).

Lesotho is also known as the Mountain Kingdom. Figure 1 3 below shows the Maloti Mountains in Lesotho.



**Figure 1-3 Photo of Lesotho's Maluti Mountains**



Source: Shutterstock

Lesotho's highlands is the source of three major river systems and the home to one of the region's principal water catchment areas, hence this makes water a valuable and sustainable asset in Lesotho (Lesotho Review 2018). Therefore, Lesotho utilises its water for hydro-electricity. Lesotho is *"home to the largest and most ambitious civil engineering project in the whole of Africa, Lesotho Highlands Water Project (LHWP), which has harnessed and commercialized her up-stream surplus water sources - often referred to by Basotho as their "White Gold" ([www.visitlesotho.travel](http://www.visitlesotho.travel))"*

The two-phase project was established in 1986 by a treaty signed by Lesotho and South Africa to provide water to the Gauteng province in South Africa and to generate hydro-electricity for Lesotho. Phase I of the LHWP included the construction of Katse and Mohale dams, 'Muela hydropower-station, and associated tunnels and reservoirs. Phase II is underway. (Lesotho Review, 2018). The below photo (Figure 1-4) shows the Katse Dam wall (LHWP Phase 1) and the surrounding landscape.

**Figure 1-4 Photo of Katse Dam which is part of the LHWP project**



Source: Shutterstock

#### 1.4.4 Economic and industrial profile

As Lesotho is landlocked by South Africa, it is subject to a limited economic base of agriculture, remittances, textile manufacturing and regional customs revenue. Lesotho only produces less than about 20% of the nation's food and imports 85% of the goods that they consume from South Africa (Lesotho Review, 2018).

The country depends greatly on South Africa for its economic activity and on the remittances from family members that work in South Africa on farms, in mines and as domestic workers. About 75% of the people in Lesotho live in rural areas and practice subsistence agriculture and animal herding.

In 2016 about 26% of total Gross Domestic Product (GDP) in Lesotho was from revenues from the Southern Africa Customs Union (SACU) as Lesotho is a member. Unfortunately due to its volatility the SACU revenue is expected to decrease. Lesotho also receives royalties from the South African Government for the LHWP hydro project. The Lesotho government continues to toughen its tax system to lessen dependency on customs duties and other transfers (Lesotho Review, 2018).

Lesotho's largest employer is the government and their largest private employer is the garment and textile industry. Garments are exported to South Africa and the US, they are manufactured in factories that are mainly worked by around 36 000 Basotho women (mainly). Diamond mining also accounts for about 35% of total exports (in 2015). Lesotho GDP was at an average of 4.5% from 2010 to 2014 but dropped to about 2.5% in 2015 to 2016.

The composition of GDP (2016/2017) by sector in Lesotho is made up of:

- Services at 54.9%;
- Industry (falls within IPPU sector) at 39.2%, and
- Agriculture (falls within AFOLU sector) at 5.8%. ([www.cia.gov](http://www.cia.gov))

#### 1.4.5 Natural resources

Lesotho despite being a small country has a vast array of natural resources. Below are the main and vast variety of natural resources that exist in Lesotho.

**Water** - one of the main prominent and important natural resource for Lesotho is water, as stated above in point 1.4.3 describing the LHWP which is a hydropower project in partnership with South Africa. Water in Lesotho has been recognised as a very valuable natural asset that is both renewable and sustainable (Lesotho Review, 2018).

**Minerals and other natural resources** – Diamonds are another one of Lesotho's imperative natural resource. In 2014 a worth of US\$300 million (240,000 carats of diamonds) was produced by the four main mines in Lesotho. They are Letšeng, Liqhobong, Mothae and Kao mines. The Letšeng mine is the world's richest mine on an average price per carat basis (Wikipedia). Other minerals in Lesotho include clay and building stone (Lesotho Review, 2018).

**Agriculture** - agriculture covers an area of 23 120 km<sup>2</sup> which is made up of arable, permanent crops and permanent pastures land ([www.fortuneofafrica.com](http://www.fortuneofafrica.com)). Agriculture historically in Lesotho was a big contributor to the gross domestic product (GDP). In the 1990s and in the early 21<sup>st</sup> century drought has led to a decrease in its contribution to the GDP. The main crops in Lesotho are corn (maize), beans, wheat, sorghum and peas. Other products produced and exported include cattle products, mohair and wool. Agriculture in Lesotho is very susceptible to climate and weather variability. (Lesotho Government, 2019).

**National Parks** – there are two main National Parks in Lesotho –the Ts'ehlanyane National Park and the Sehlabathebe National Park. A vast assortment of wildlife (fauna) is found in these parks – Porcupine,

Common Eland, Cape Clawless Otter, Smith's Red Rock Hare, Mountain Rhebuck, Sloggett's Vlei Rat, Baboons, Rock Dassie, Caracal, Black-backed Jackal and Serval Cat (Lesotho Review, 2018).

**Forestry and Fishing** - in Lesotho, timber cutting is mainly used for fuel. In reference to fishing, in Lesotho fishing comes from inland waters, the main fish that are caught include rainbow trout, the common carp and catfish to a smaller scale.

## 1.4.6 GHG Sectors in Lesotho

### 1.4.6.1 Energy in Lesotho

The main transport network in Lesotho is road, which makes up 70% of domestic travel needs. The other types include: air, ferry boats at river crossings, limited rail services, animal transport and pedestrian travel (Lesotho Review 2018).

In reference to air travel, the Moshoeshoe International Airport (MIA) is about 20 km outside of Maseru. 12 out of its 24 airstrips are being utilised as Lesotho's domestic air transport services providing primary and secondary access to the most isolated rural areas. The two of the airstrips have tarred runways, others are gravel and grass airstrips and they are mainly used by the Lesotho Flying Doctors Service. The Lesotho Defence Force (LDF) Airwing located north-east of Maseru has three fixed-wing aircraft and six helicopters out of Mejametalana Airbase (Lesotho Review, 2018).

Some key electricity statistics for the country are as follows:

- Total population having access to electricity is 17%;
- Electricity in urban areas is 43%, and
- Electricity in rural areas is 8%. (Lesotho Review 2018)

Lesotho produces all its electricity from hydropower.

### 1.4.6.2 Industrial Processes and Product Use in Lesotho

In 2016 the tertiary sector (wholesale and retail trade, restaurants and hotels, transport and communications, financial intermediation, real estate and business services, public administration, education, health and social work, and community, social and personal services) and makes up about 55 % of Lesotho's GDP.

The secondary sector (e.g: food and beverages and textiles and clothing industry) also recorded positive growth, although activity in the manufacturing subsector slowed.

The primary sector (including mining and agriculture) also grew in 2016. The biggest growth was in the mining and quarrying subsector (by 9.6%).

The greatest significant manufacturing subsectors in Lesotho are textiles and garments, plastic products, food and beverages, consumer electrical and electronic appliances, automotive components, packaging material and garment accessories (zippers and buttons). The biggest contributor and influencer of manufacturing to the GDP is textiles and garments. (Lesotho Review 2018)

### 1.4.6.3 Agriculture, Forestry and other Land Use in Lesotho

Agriculture is the prevailing primary sector. The arable subsector is made up of rain-fed cereal production, while the livestock subsector is made up of widespread animal grazing, wool and mohair production, and a fast-growing aquaculture industry. Between 2001 and 2011 the percentage contribution to GDP in the

livestock subsector increased to 62% from 47.2%, while the crops and horticulture subsectors decreased by almost half.

Farming is an important livelihood activity for a significant percentage of the population due to the fact that about 70% of Lesotho's people live in rural areas. Agriculture remains one of the backbones of the economy. The livestock subsector includes largely sheep, cattle, goats, poultry and pigs. The livestock subsector is one of the country's most important contributors to the GDP.

In Lesotho about 1.6% of land is covered in forests with a current deforestation rate of 0.5% per year. Around 11% of Lesotho's total land area is projected to be arable, and only a small percentage of this is currently used for irrigated crop production. The main crops are maize (60% of agricultural land), sorghum (20% of agricultural land), wheat (10% of agricultural land), peas and beans (Lesotho Review, 2018).

#### 1.4.6.4 Waste in Lesotho

In 2006 the baseline assessment for the development of an Integrated Solid Waste Management System (ISWMS) for Maseru City report identified that due to the fast growing rate (about 7% in 2006), the city of Maseru has resulted in overburdened urban infrastructure and services, including cleansing services. Hence, the environmental problems need to be addressed which are as a result of poor waste management and unplanned urban growth.

The municipality in Maseru only has collection and disposal services. A small percentage of solid waste is collected and disposed of at the Tšosane dumpsite. The city of Maseru has the following problems: streets are dirtied with litter, dark corners and passages of buildings are used for waste disposal, there is litter, flies, rats and foul smells in storm water drainage systems, gullies in residential areas have paper, plastic and cans and rusting vehicle bodies. Consequently, the Government of Lesotho has commissioned a baseline assessment as a step towards the development of an ISWMS. (Koaleli, Lombard, Phomane, Thamae, 2006)

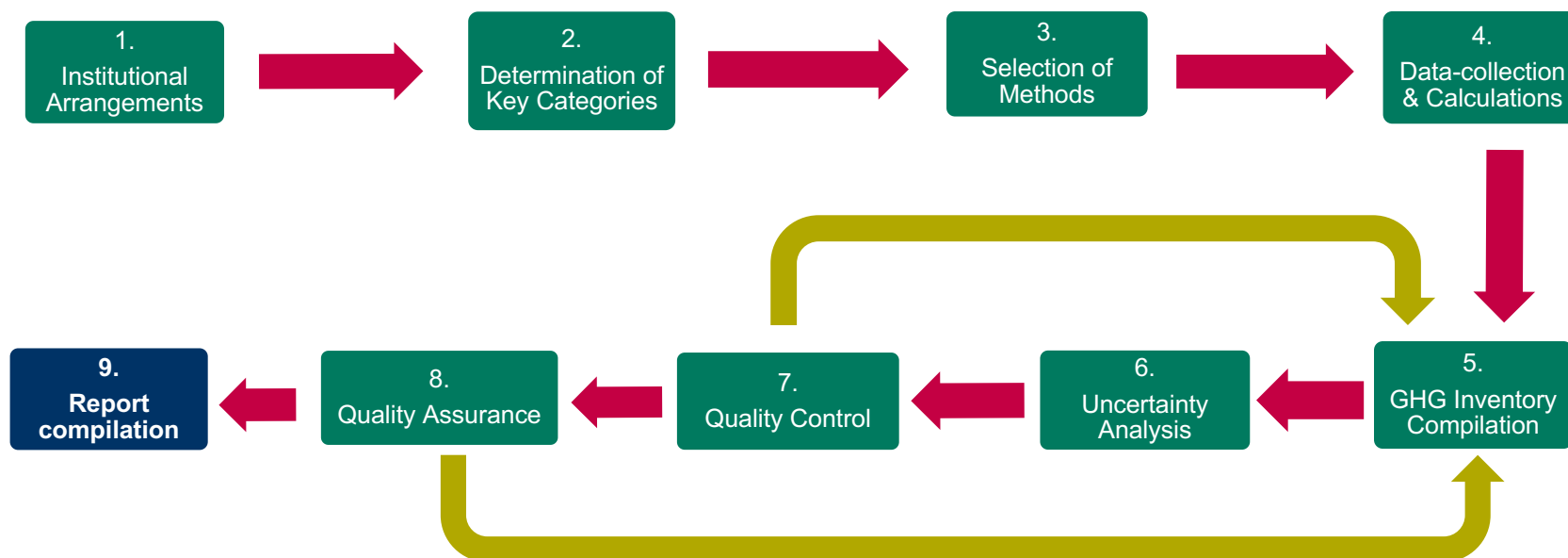
Funded by the European Union (EU) *"the Maseru Waste Water Project is helping to improve the treatment and disposal of wastewater for around 100 000 residents in the urban and peri-urban areas of Maseru through connections to sewer networks as well as building low-cost on-site sanitation services"* (Lesotho Review, 2018).



## 2. 4<sup>TH</sup> INVENTORY PREPARATION

This 4<sup>th</sup> National GHG Inventory Report was compiled following a nine step process shown in Figure 2-1 below, in line with the recommendations of the Consultative Group of Experts.

**Figure 2-1 Stages followed in compiling the 4<sup>th</sup> National GHG inventory**



Firstly institutional arrangements were confirmed, followed by the determination of the key categories from the 3<sup>rd</sup> National GHG Inventory. The third, fourth and fifth steps were to select the appropriate methods to be used for calculating the emissions, data-collection and GHG inventory calculation and compilation respectively. The GHG inventory compilers then undertook uncertainty analyses for their respective activities. In the 7<sup>th</sup> step, quality controllers for each sector carried quality control (QC) checks on the respective sectors and where necessary returned the inventories to the compilers to address any identified issues. Once all issues had been addressed the inventories underwent Quality Assurance (QA) process, which also referred any identified issues to the GHG inventory compilers. Then the sectorial inventories that successfully passed the QC and QA steps were used to compile the 4<sup>th</sup> National GHG inventory report.

The below sections provide a detailed breakdown of each stage in this GHG inventory compilation process.

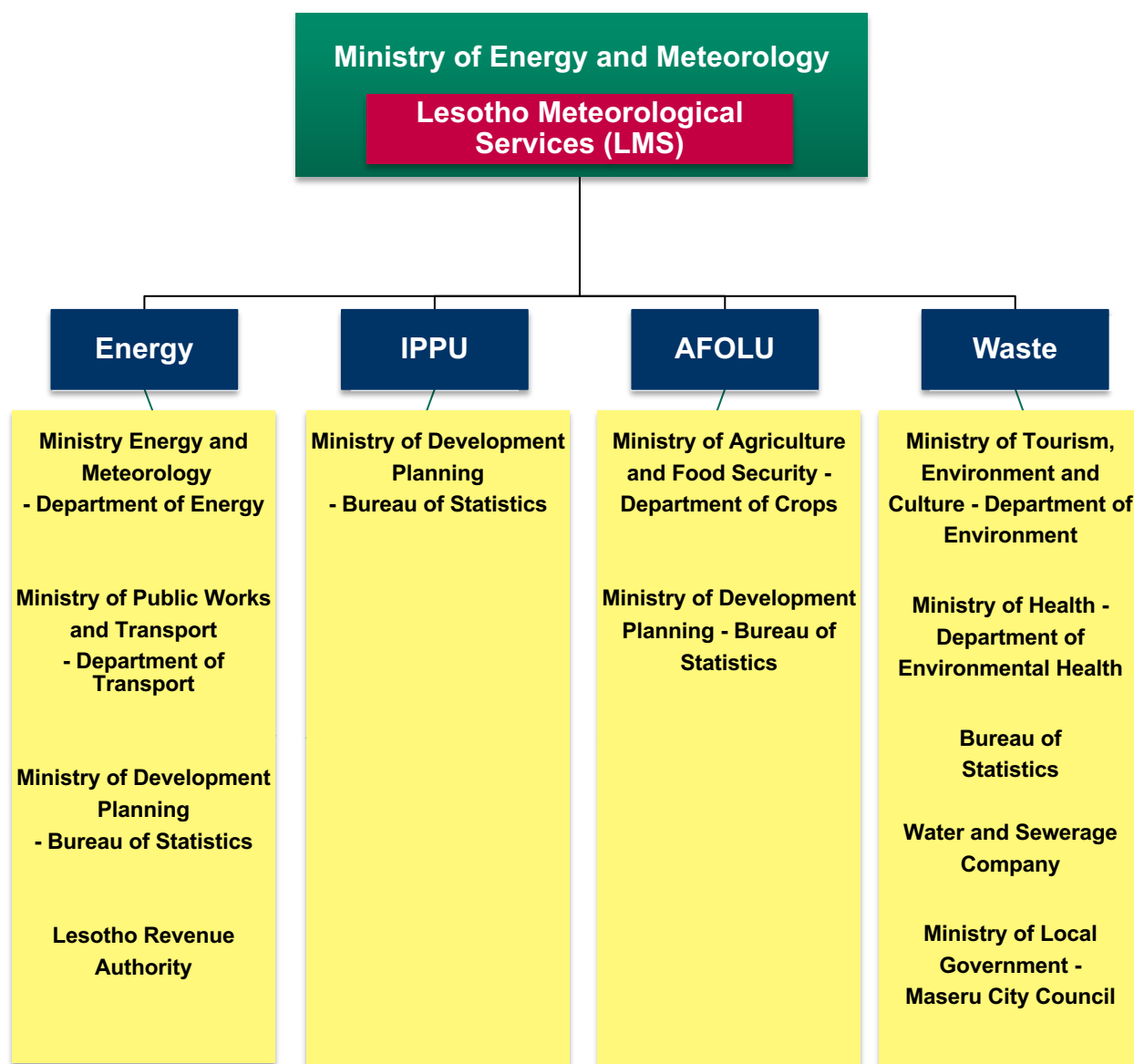
## 2.1 Institutional Arrangements

This covered the following activities:

- Confirming institutional arrangements and roles;
- Determining work plan;
- The quality assurance;
- The data collection tools;
- Training.

Figure Figure 2-2 below presents the institutional arrangements for compilation of Lesotho's 4<sup>th</sup> National GHG inventory.

**Figure 2-2 Institutional arrangements for the GHG compilation**



LMS is the national inventory agency with the overall responsibility for compiling the national GHG inventories. Other departments and institutions supported LMS with data and expert input. Figure 2-2 shows the full institutional arrangements.

Each sector in the GHG compilation has a number of national departments and institutions that contribute to data-collection. Below is a breakdown of each institutional arrangement and their various roles.

**Table 2-1 Roles of the Institutions in the Energy sector**

Ministry / Agency	Role
Department of Energy	<ul style="list-style-type: none"> <li>■ Provides information on: <ul style="list-style-type: none"> <li>▪ National Energy Balances</li> <li>▪ Imports of petroleum fuels</li> </ul> </li> </ul>
Bureau of Statistics	<ul style="list-style-type: none"> <li>■ Provides energy data in the form of annual energy reports</li> </ul>
Department of Transport	<ul style="list-style-type: none"> <li>■ Provides vehicle statistics</li> </ul>
Lesotho Revenue Authority	<ul style="list-style-type: none"> <li>■ Provides annual vehicle imports</li> </ul>
Ministry of Defence Force	<ul style="list-style-type: none"> <li>■ Provides data on Fuel for the Ministry</li> </ul>
Mission Aviation Fellowship	<ul style="list-style-type: none"> <li>■ Provides data for Fuel</li> </ul>

**Table 2-2 Roles of the Institutions in the IPPU sector**

Ministry / Agency	Role
Lesotho Meteorological Services – Ozone Unit	<ul style="list-style-type: none"> <li>■ Provides quantities of HFCs consumed / imported</li> </ul>
Bureau of Statistics	<ul style="list-style-type: none"> <li>■ Provides refrigeration data</li> </ul>
Lesotho Meteorological Services	<ul style="list-style-type: none"> <li>■ Collects data on: <ul style="list-style-type: none"> <li>▪ Ceramics and bricks</li> <li>▪ Beverages</li> </ul> </li> </ul>

**Table 2-3 Roles of the Institutions in the AFOLU sector**

Ministry / Agency	Role
Department of Crops	<ul style="list-style-type: none"> <li>■ Provides information on: <ul style="list-style-type: none"> <li>▪ Fertilizer, urea &amp; lime application info;</li> <li>▪ Cultivated area per year;</li> <li>▪ Landcover atlas,</li> <li>▪ Agricultural production survey – crops.</li> </ul> </li> </ul>
Bureau of Statistics	<ul style="list-style-type: none"> <li>■ Provides the Lesotho Agricultural Census Report and Livestock Report</li> </ul>



**Table 2-4 Roles of the Institutions in the Waste sector**

Ministry / Agency	Role
Department of Environment	<ul style="list-style-type: none"> <li>■ Provides information on solid waste per capita for Maseru and Lesotho</li> <li>■ Provides information on Open Burning of waste</li> </ul>
Department of Environmental Health	<ul style="list-style-type: none"> <li>■ Provides information on incineration of medical waste</li> </ul>
Bureau of Statistics	<ul style="list-style-type: none"> <li>■ Provides information on population data and solid waste</li> </ul>
Water and Sewerage Company	<ul style="list-style-type: none"> <li>■ Provides information on Waste Water Treatment - Domestic Waste</li> </ul>
Maseru City Council	<ul style="list-style-type: none"> <li>■ Provides information on solid waste per capita for Maseru and Lesotho</li> <li>■ Provides information on Sludge for Ts'oeneng</li> <li>■ Provides information on Open Burning of waste</li> </ul>

## 2.2 Determination of Key and New Categories

Generally this step should entail identification of the Key Categories identified in the Key Category Analyses from the preceding GHG inventory. Unfortunately Lesotho's 3<sup>rd</sup> GHG inventory report did not contain any key category analyses results, hence a level key category analysis was carried out by the 4<sup>th</sup> GHG inventory team using the results of the 3<sup>rd</sup> GHG inventory. New categories that were not included in the 3<sup>rd</sup> GHG inventory were also identified in this step.

### 2.2.1 Level Key Categories based on 3<sup>rd</sup> GHG inventory

The analysis was performed using the Tier 1 level (L1) method for the 3<sup>rd</sup> GHG inventory result for the year 2010. The table below (Table 2-5) shows the results of the level key category analysis based on the 2010 GHG inventory.

**Table 2-5 2010 Level Key Categories from the 3<sup>rd</sup> GHG Inventory**

Category Code	Category	Gas	2010 Estimate (Gg CO <sub>2e</sub> )	2010 Absolute Value	Level Assessment (%)	Cumulative Total (%)
1A4b	Residential	CO <sub>2</sub>	1 227.51	1 227.51	23.91 %	23.91 %
3A1	Enteric fermentation	CH <sub>4</sub>	889.25	889.25	17.32 %	41.22 %
3C4	Direct emissions from agricultural soils	N <sub>2</sub> O	601.07	601.07	11.71 %	52.93 %
1A4a	Commercial / Institutional	CO <sub>2</sub>	506.07	506.07	9.86 %	62.78 %
3A2	Animal Waste Management Systems	N <sub>2</sub> O	461.9	461.90	9.00 %	71.78 %
1A3b	Road transport	CO <sub>2</sub>	323.95	323.95	6.31 %	78.09 %
1A4b	Residential	CH <sub>4</sub>	261.15	261.15	5.09 %	83.17 %
4D	Waste water treatment and discharge	CH <sub>4</sub>	236.00	236.00	4.60 %	87.77 %

3C5	Indirect emissions from agricultural soils	N <sub>2</sub> O	171.95	171.95	3.35 %	91.12 %
1A4a	Commercial / Institutional	CH <sub>4</sub>	95.58	95.58	1.86 %	92.98 %
3C1	Prescribed burning of savannas	CH <sub>4</sub>	76.98	76.98	1.50 %	94.48 %
3C1	Prescribed burning of savannas	N <sub>2</sub> O	75.99	75.99	1.48 %	<b>95.96 %</b>

The tables below show a summary of the key categories by level, per sector. There were no key categories from the IPPU sector.

## Energy

**Table 2-6 Key Categories for Energy Sector**

Category Code	Key Category	Greenhouse Gases
1A3b	Road	CO <sub>2</sub>
1A4a	Commercial / Institutional	CO <sub>2</sub>
1A4b	Residential	CO <sub>2</sub> , CH <sub>4</sub>

## AFOLU

**Table 2-7 Key Categories for AFOLU Sector**

Category Code	Key Category	Greenhouse Gases
3A1	Enteric fermentation	CH <sub>4</sub>
3A2	Animal Waste Management Systems	N <sub>2</sub> O
3C1	Prescribed burning of savannas	CH <sub>4</sub> , N <sub>2</sub> O
3C4	Direct emissions from agricultural soils	N <sub>2</sub> O
3C5	Indirect emissions from agricultural soils	N <sub>2</sub> O

## Waste

**Table 2-8 Key Categories for Waste Sector**

Category Code	Key Category	Greenhouse Gases
4D	Waste water treatment and discharge	CH <sub>4</sub>

### 2.2.2 New categories not included in 3<sup>rd</sup> GHG inventory

The GHG inventory team identified the following new emission categories for this 4<sup>th</sup> inventory, which were not included in the 3<sup>rd</sup> National GHG inventory. These were then included in this inventory as part of continuous improvement of the country's national GHG inventory.

The below table (Table 2-9) shows the additional new categories that were added to the existing 4<sup>th</sup> GHG inventory after the workshop. However, due to unavailability of activity data, GHG emission calculations for cement production could not be carried out, hence this category was excluded from the final GHG inventory.

**Table 2-9 New Categories for this 4<sup>th</sup> GHG inventory**

Category Code	New Category	Greenhouse Gases
<b>IPPU</b>		
2A1	Cement production (This category was subsequently dropped due to unavailability of information and data)	CO <sub>2</sub>
2F1	Refrigeration and Air Conditioning	HFCs
2H2	Food and Beverages industry	CO <sub>2</sub>

## 2.3 Data-collection procedures

For data-collection, LMS as the national inventory agency, set up an internal GHG inventory team. Within that team each sector had a team lead, additional team members (if needed) and quality controllers (see section 2.5.). Hence each team lead and members were responsible for their sector (see authors and contributors). Each sector team coordinated and oversaw the collection of data from the other institutions, the GHG calculations, data documentation and quality control for each sub-sector.

ERM and the LMS team created a data-requirements list and work plan for each sector aligned with the established institutional arrangements. Thereafter, each LMS team lead was responsible to liaise with the relevant institutions and departments to collect the required data and later to process and do the calculations of that data. Data access and collection of required data was a challenge for this inventory. In some instances, only certain year's data was available, some were only financial years and not calendar years and some of the data received was verbal and not documented.

Table 2-10 below lists all the sources of data for compiling this 4<sup>th</sup> National GHG inventory.

## 2.4 Methodologies

This 4<sup>th</sup> GHG inventory report used the 2006 IPCC Guidelines for estimating the emissions for Lesotho for the years 2011 until 2017. As far as possible the highest Tier methodologies possible were used. Chapters 4 to 7 present the detailed breakdown of the methodologies used for each sector and emission category.

The Global Warming Potentials (GWPs) of the Second Assessment Report (SAR) of the Intergovernmental Panel on Climate Change were used consistently throughout this inventory (see Units and factors).

**Table 2-10 Data sources**

Category	Greenhouse Gases	Data Sources
1 Energy		
1A Fuel Combustion Activities		
1A2 Manufacturing Industries and Construction	CO <sub>2</sub> CH <sub>4</sub> N <sub>2</sub> O	<ul style="list-style-type: none"><li>■ Department of Energy</li><li>■ 2015 and 2016 BOS Energy Reports</li></ul>
1A3 Transport		
1A3a Civil Aviation	CO <sub>2</sub> CH <sub>4</sub> N <sub>2</sub> O	<ul style="list-style-type: none"><li>■ Department of Energy</li><li>■ 2015 and 2016 BOS Energy Reports</li><li>■ Lesotho's 3<sup>rd</sup> National GHG Inventory for 2005 - 2010</li></ul>
1A3b Road Transport	CO <sub>2</sub> CH <sub>4</sub> N <sub>2</sub> O	
1A4 Other Sectors		
1A4a Commercial / Institutional	CO <sub>2</sub> CH <sub>4</sub> N <sub>2</sub> O	<ul style="list-style-type: none"><li>■ Department of Energy</li><li>■ 2015 and 2016 BOS Energy Reports</li><li>■ Lesotho's 3<sup>rd</sup> National GHG Inventory for 2005 - 2010;</li></ul>
1A4b Residential	CO <sub>2</sub> CH <sub>4</sub> N <sub>2</sub> O	
1A4c Agriculture / Forestry / Fishing / Fish Farms	CO <sub>2</sub> CH <sub>4</sub> N <sub>2</sub> O	
2 IPPU		
2A Mineral Industry		
2A4 Other Process Uses of Carbonates		
2A4a Ceramics	CO <sub>2</sub>	<ul style="list-style-type: none"><li>■ U.S Geological Survey minerals yearbooks (2015 and 2016);</li><li>■ Loti Brick</li></ul>
2F Product Uses as Substitutes for Ozone Depleting Substances		
2F1 Refrigeration and Air Conditioning		
2F1a Refrigeration and Stationery Air Conditioning	HFCs	<ul style="list-style-type: none"><li>■ LMS Ozone Unit</li></ul>

**2H Other***2H2 Food and Beverages industry**CO<sub>2</sub>**Maluti Mountain Breweries***3 AFOLU****3A Livestock***3A1 Enteric Fermentation**CH<sub>4</sub>*

- Bureau of Statistics;
- IPCC 2006 Guidelines.

*3A2 Manure Management**CH<sub>4</sub> N<sub>2</sub>O*

- Bureau of Statistics;
- Lesotho National GHG Inventory for 2010;

**3B Land***3B1 Forest Land**CO<sub>2</sub>*

- Food and Agriculture Organisation;
- Forest Resource Assessment.

**3C Aggregate sources and non-CO2 emissions sources on land***3C1 Emissions from biomass burning**CH<sub>4</sub> N<sub>2</sub>O*

- Food and Agriculture Organisation

*3C3 Urea Application**CO<sub>2</sub> CH<sub>4</sub> N<sub>2</sub>O*

- Ministry of Food and Agriculture, Department of Crops

*3C4 Direct N<sub>2</sub>O emissions from managed soils**N<sub>2</sub>O*

- Ministry of Agriculture and Food Security

*3C5 Indirect N<sub>2</sub>O emissions from managed soils**N<sub>2</sub>O*

- Ministry of Agriculture and Food Security

*3C6 Indirect N<sub>2</sub>O Emissions from Manure Management**CO<sub>2</sub> CH<sub>4</sub> N<sub>2</sub>O*

- Bureau of Statistics;
- Lesotho's 3<sup>rd</sup> National GHG Inventory for 2005 - 2010

**4 Waste****4A Solid Waste Disposal***CH<sub>4</sub>*

- 2006 Lesotho Population and Housing survey
- 2011 Demographic survey
- 2016 Lesotho Population and Housing survey
- 2006 Baseline Assessment study for ISWMS for Maseru

**4C Incineration and open burning of waste**

<b>4C Waste Incineration and Open Burning of Waste</b>	<b>CO<sub>2</sub> CH<sub>4</sub> N<sub>2</sub>O</b>	<ul style="list-style-type: none"> <li>■ 2006 Lesotho Population and Housing survey</li> <li>■ 2011 Demographic survey</li> <li>■ 2016 Lesotho Population and Housing survey</li> <li>■ 2006 Baseline Assessment study for ISWMS for Maseru</li> <li>■ COWI Lesotho Healthcare Waste Study Report 2012</li> </ul>
<b>4D Waste water treatment and discharge</b>	<b>CH<sub>4</sub> N<sub>2</sub>O</b>	<ul style="list-style-type: none"> <li>■ 2006 Lesotho Population and Housing survey</li> <li>■ 2011 Demographic survey</li> <li>■ 2016 Lesotho Population and Housing survey</li> </ul>

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## 2.5 QA / QC Plan

A QA/QC plan is necessary in order to have transparency, accuracy, completeness, comparability and consistency in a national inventory. That plan must comprise of aspects that include methodologies used, assumptions, uncertainties, data used and formats among other things.

For this inventory a QA/QC plan was developed in order to plan, prepare and manage the inventory activities correctly. With the consideration of available data, resources, expertise and the characteristics of the inventory the existing QA/QC plan was developed. Various activities and procedures were then conducted in order to fulfil that QA/QC plan.

The aspects that were defined in or for the QA/QC plan incorporated:

- Institutional arrangements;
- Detailed work plan and schedule;
- Responsibilities;
- Data requirements;
- Data collection;
- QC activities;
- QA activities;
- Uncertainty assessment;
- Reporting and data storage process.

### 2.5.1 Quality Control

Quality control is the process that is followed while the inventory is being compiled by the team that is compiling the inventory. This is done in order to evaluate and conserve the quality of the inventory by having routine technical activities.

The following QC checks on activities and procedures (Table 2-11) were followed during the compilation of this 4<sup>th</sup> GHG national inventory.

**Table 2-11 Quality Control**

QC Activity	Methods followed / procedures
Activity data QC	<ul style="list-style-type: none"><li>■ Check the temporal consistency of the activity data;</li><li>■ Check the consistency of the units.</li></ul>
EF data QC	<ul style="list-style-type: none"><li>■ IPCC default EF:<ul style="list-style-type: none"><li>• Check default EF applicability;</li><li>• Check temporal consistency;</li><li>• Check the consistency of the units.</li></ul></li></ul>



General data QC	<ul style="list-style-type: none"> <li>■ Check the data calculations: <ul style="list-style-type: none"> <li>• Reproduce a set of emission/removal calculations;</li> <li>• Calculate Implied Emission Factor.</li> </ul> </li> <li>■ Check any recalculation data;</li> <li>■ Check that emission and removal data are correctly aggregated from lower ;reporting levels;</li> <li>■ Check that the data is compared to previous estimates;</li> <li>■ Check for consistency in the trend;</li> <li>■ Check for completeness of each subcategory.</li> </ul>
Uncertainty QC	<ul style="list-style-type: none"> <li>■ Check that expert judgement is recorded;</li> <li>■ Check uncertainty calculations.</li> </ul>
Database QC	<ul style="list-style-type: none"> <li>■ Check that the data is in the database;</li> <li>■ Check for transcription errors;</li> <li>■ Check uncertainty is in the database;</li> <li>■ Check for transcription errors in uncertainty data;</li> <li>■ Check the correct units have been used in the database;</li> <li>■ Check the labels in the database are correct;</li> <li>■ Check that data sources / references have been correctly recorded;</li> <li>■ Check the correct conversion factors are used;</li> <li>■ Check data aggregations are correct;</li> <li>■ Check the uncertainty aggregations are correct;</li> <li>■ Check that original and supporting documents are attached.</li> </ul>
Supporting data	<ul style="list-style-type: none"> <li>■ Check all supporting data and references are stored in the web-based data-collection tool or sector folders.</li> </ul>
Reporting	<ul style="list-style-type: none"> <li>■ Check that the activity and EF data have been added into the report;</li> <li>■ Check if there is proper citation of references;</li> <li>■ Check that uncertainty data is added in;</li> <li>■ Check that completeness is acknowledged;</li> <li>■ Check the comparisons and trends with previous estimates;</li> <li>■ Check that explanations are provided for any data differences;</li> <li>■ Check that the QC/QA procedures have been included.</li> </ul>

For some of the above aspects a QC sheet was developed to check and verify data collections, uncertainty and the database as data was being compiled, the full QC sheet is included in Appendix B.

### 2.5.2 Quality Assurance

Quality assurance is conducted by a person / persons (independent third parties) that are not directly involved in the compilation of the inventory. This is done via a system of review procedures once the inventory is complete and has gone through the internal QC process while being compiled.

The review results in

- 
- Ensuring that the inventory represents the best possible estimates of emissions and removals given the current state of scientific knowledge and data availability;
  - Verifying that measurable objectives were met;
  - Supporting the effectiveness of the QC programme.

The QA process that was followed in this inventory included a two-phase quality assurance process. Firstly, quality assurance was carried out by the ERM team. Secondly, quality assurance will be undertaken by an independent third party that will be appointed by LMS. This stage of the QA system will be performed once this inventory is complete. Additionally, ERM will assist with provision of data in this quality assurance process where required.

## **2.6 Evaluating Uncertainty**

Uncertainty analyses were carried out for each emission category based on the 2006 IPCC Guidelines. Tier 1 uncertainty methods were used. The specific uncertainty analyses methods and approaches used are dependent on each category and have been outlined in detail under each category.

### 3. TRENDS IN LESOTHO'S GHG EMISSIONS

This section presents the trends in Lesotho's GHG emissions over the years. Firstly, the overall results of this 4<sup>th</sup> National GHG inventory are presented, followed by a trend analysis of Lesotho's GHG inventories covering the results of all the four GHG inventories for Lesotho.

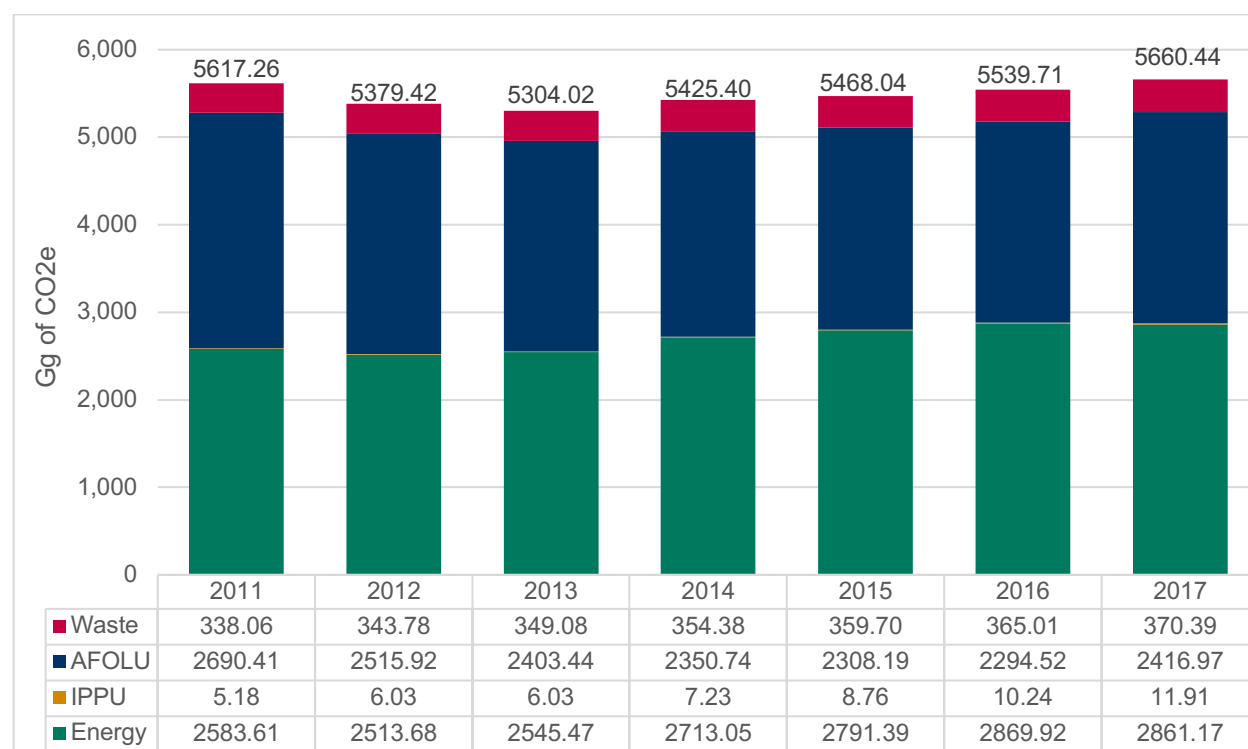
#### 3.1 Results of 4<sup>th</sup> GHG Inventory

This section presents the overall results of this 4<sup>th</sup> National GHG Inventory for Lesotho for the time series of 2011 until 2017. Chapters 4, 5, 6 and 7 below then present the full details and results of Energy, IPPU, AFOLU and Waste sectors of this 4<sup>th</sup> GHG inventory respectively.

Figure 3-1 below presents an overview of the results of the 4<sup>th</sup> GHG inventory, showing the GHG emissions for each year between 2011 and 2017. The Figure shows that Lesotho's emissions were at 5 617.26 Gg CO<sub>2</sub>e in 2011, then declined slightly between 2011 and 2013 to 5 304.02 Gg CO<sub>2</sub>e in 2013 before increasing again over the next four years to 5 660.44 in 2017. The decrease in the emissions over the 2011 – 2013 period is due to decrease in energy sector emissions resulting from decreased energy consumption over that period as well as decrease in AFOLU emissions.

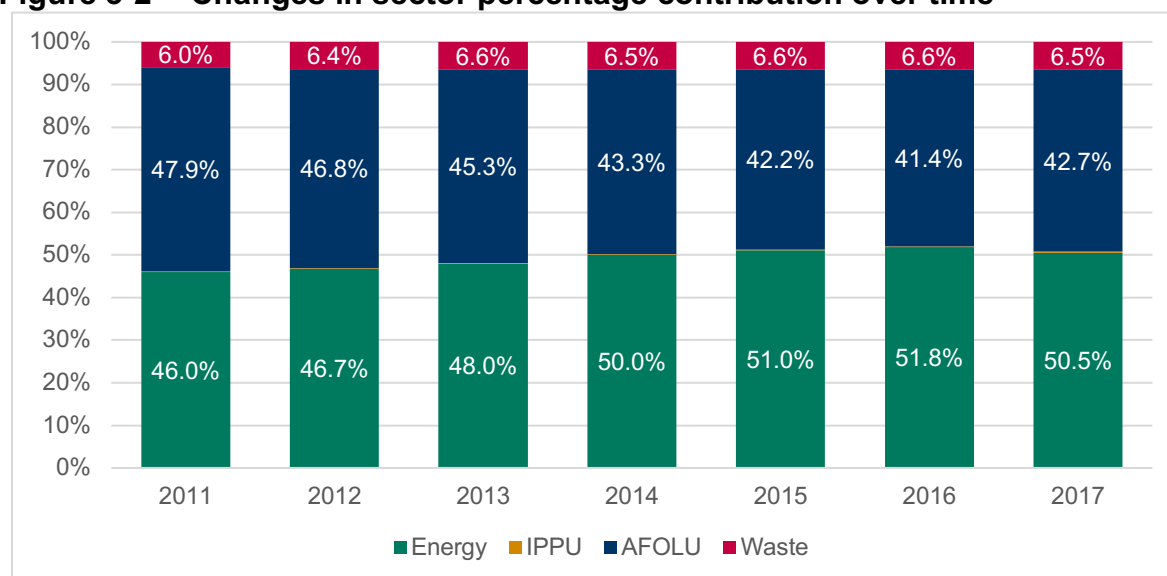
The AFOLU sector was the largest contributor to the national GHG emissions in 2011 at 2 690.41 Gg CO<sub>2</sub>e (47.9%), followed by the energy sector at 2 583.61 Gg CO<sub>2</sub>e (46%). By 2017 the energy sector had become the largest contributor to the inventory at 2 861.17 Gg CO<sub>2</sub>e (50.5%) followed by AFOLU at 2 416.97 Gg CO<sub>2</sub>e (42.7%). The waste sector contributed between 6.02% (in 2011) and 6.54% (in 2017), while the IPPU sector was the least contributor throughout the period averaging 0.14%.

**Figure 3-1 Lesotho's net GHG emissions for the period 2011 – 2017, by sector**



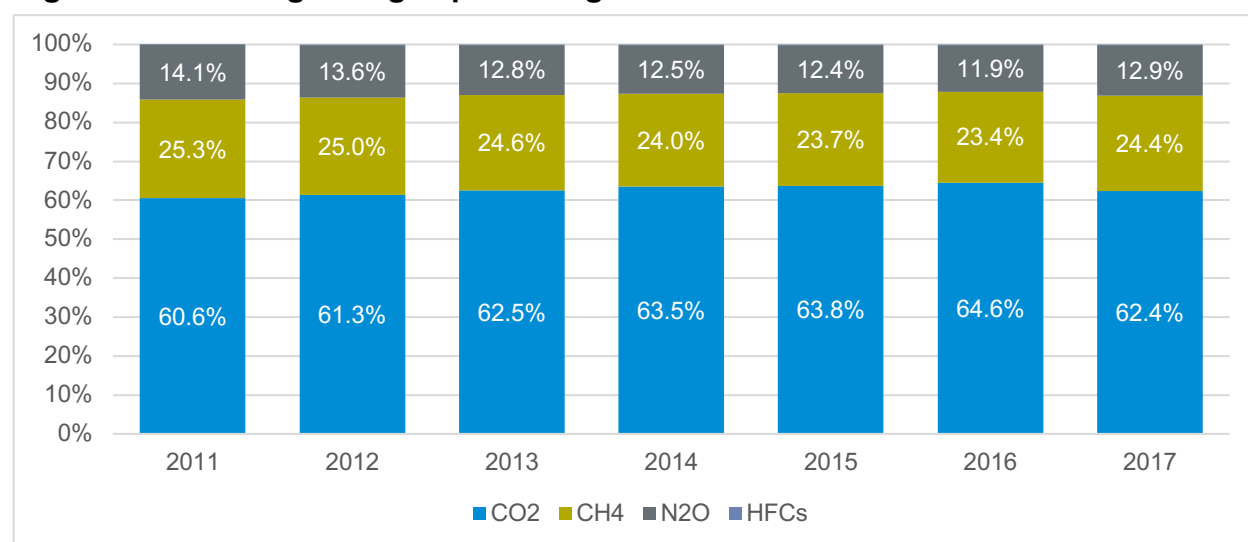
The below figure (Figure 3-2) shows the change in the percentage contribution of the sectors to the national GHG inventory over the period 2011 - 2017. The IPPU sector emissions are very small, ranging between 0.08 and 0.09%.

**Figure 3-2 Changes in sector percentage contribution over time**



In terms of greenhouse gas contribution, carbon dioxide has been the most prominent gas in Lesotho's GHG inventories, contributing between 60.6% in 2011 and 64.6% in 2016 (Figure 3-3). On average, methane and Nitrous oxide have contributed 24.2% and 13.0% respectively over the period 2011 – 2017. HFCs have been the least contributors to the country's GHG inventory throughout the period of the assessment. The collective contribution of HFC-32, HFC-125, HFC-134a and HFC-143a ranged from 0.06% in 2011 to 0.21% by 2017.

**Figure 3-3 Changes in gas percentage contribution over time**

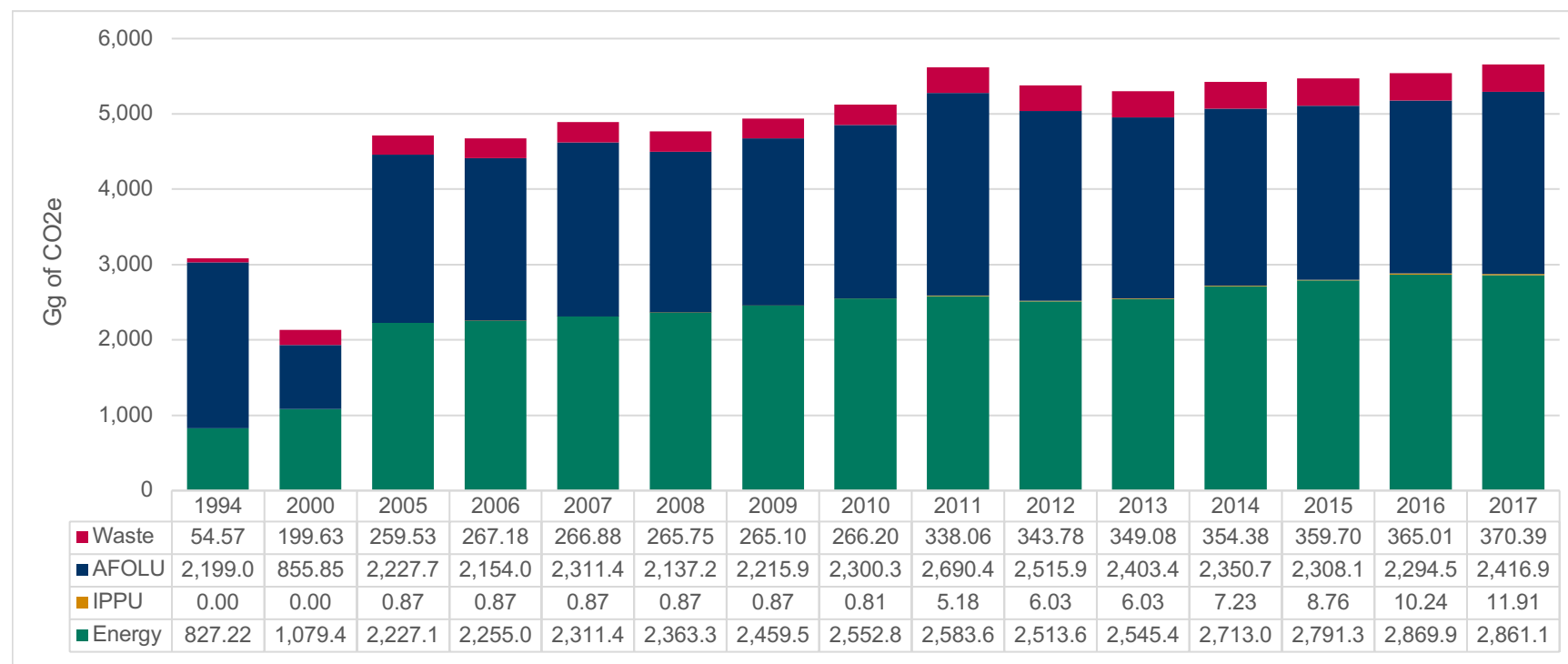


The full GHG inventories for each year between 2011 and 2017 can be found in Appendix C.

### 3.2 Emission trends 1994 – 2017

Figure 3-4 presents the trends in Lesotho's GHG emissions from 1994 to 2017. According to the Figure, the country's GHG emissions have increased by 83.7% from 3 080.7 Gg CO<sub>2</sub>e in 1994 to 5 660.44 Gg CO<sub>2</sub>e in 2017. The waste sector emissions have increased by 574.7% while the energy sector increased by 245.9%.

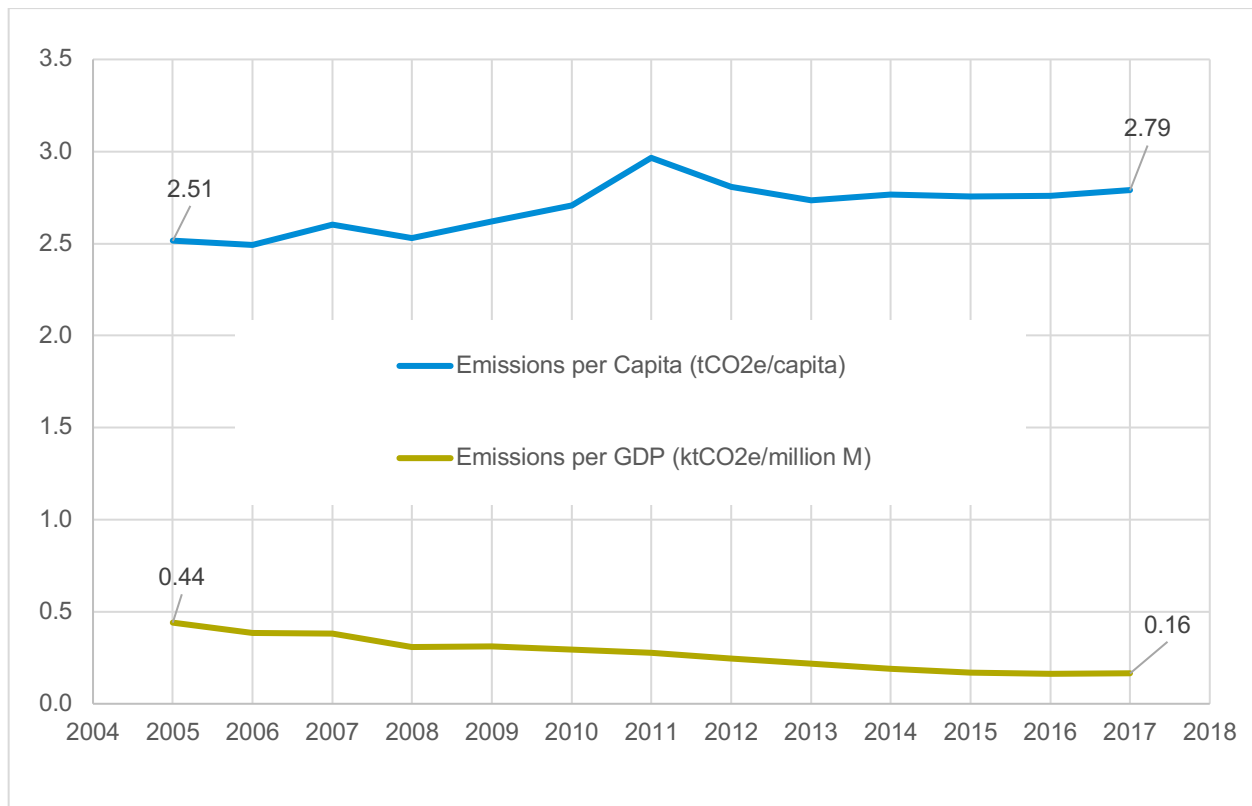
**Figure 3-4 Totals per sector in Gg of CO<sub>2</sub>e emissions from 1994 until 2017**



Since annual GHG inventories have been compiled (from 2005), a consistent time-series of the GHG inventory has been achieved. Since 2005, Lesotho's GHG emissions have grown by 20.4% from 4 715.30 Gg CO<sub>2</sub>e to 5 660.44 Gg CO<sub>2</sub>e in 2017. While this growth is primarily due to the growth of the economy, it is also partly due to the improvement in the quality of the country's GHG inventories, in terms of accuracy and completeness, overtime.

In 2005 Lesotho's net GHG emissions per capita were estimated at 2.51 tCO<sub>2</sub>e per capita. This value increase by 11.16% over the 12 years to 2.79 tCO<sub>2</sub>e per capita (Figure 3-5). On the other hand, **Error! Reference source not found.** shows that the country has achieved a slight decoupling of GHG emissions and economic growth. The carbon intensity of the economy has decreased by more than 60% from 0.44 ktCO<sub>2</sub>e per million Maloti in 2005 to 0.16 ktCO<sub>2</sub>e per million Maloti in 2017.

**Figure 3-5 Other low carbon indicators**





### 3.3 4<sup>th</sup> GHG Inventory Key Categories

The below table identifies the key categories, by level, from the 2017 GHG Inventory for Lesotho.

**Table 3-1 2017 Level Key Categories from this 4<sup>th</sup> GHG Inventory**

Category Code	Category	Gas	2017 Estimate (Gg CO <sub>2e</sub> )	2017 Absolute Value	Level Assessment (%)	Cumulative Total (%)
1A4b	Residential	CO2	1553.25	1553.25	27.44%	27.44%
3B1	Forest land	CO2	1089.55	1089.55	19.25%	46.69%
3A1	Enteric Fermentation	CH4	669.65	669.65	11.83%	58.52%
1A3b	Road Transport	CO2	455.77	455.77	8.05%	66.57%
3C4	Direct emissions from managed soils	N2O	408.85	408.85	7.22%	73.79%
1A4a	Commercial / Institutional	CO2	358.75	358.75	6.34%	80.13%
1A4b	Residential	CH4	300.06	300.06	5.30%	85.43%
4A	Solid Waste Disposal	CH4	236.61	236.61	4.18%	89.61%
3C6	Indirect emissions from managed soils	N2O	135.11	135.11	2.39%	92.00%
3A2	Manure Management	N2O	62.78	62.78	1.11%	93.11%
1A2	Manufacturing Industries and Construction	CO2	60.82	60.82	1.07%	94.18%
1A4a	Commercial / Institutional	CH4	51.89	51.89	0.92%	95.10%

## 4. ENERGY SECTOR

### 4.1 An overview of the Energy sector

Lesotho uses hydro-electricity (generated within the country), this is also supplemented with imports from neighbouring countries when there is peak consumption. The consumption of biomass fuel has surpassed its manageable supply, consequently, the population relies on supplementary energy sources that consist of agricultural residues and cattle dung. About 90% of rural households in Lesotho use biomass for thermal energy and cooking. Due to the fact that a large portion of biomass is from the informal sector, this results in poor accurate energy figures for Lesotho. Biomass consumption (wood, agricultural residues and cow dung) is the main source of domestic energy and energy in small-scale commercial sectors.

All the electricity generated in the country comes from hydroelectric plants. Biomass consumption in Lesotho is the main source of domestic energy (Lesotho Review, 2018).

### 4.2 Emission Sources

Lesotho GHG national inventory for the Energy sector is made up of the following sources:

- 1A2 Manufacturing Industries and Construction
- 1A3 Transport
  - 1A3a *Civil Aviation*
  - 1A3b *Road Transport*
- 1A4 Other Sectors
  - 1A4a *Commercial / Institutional*
  - 1A4b *Residential*
  - 1A4c *Agriculture / Forestry / Fishing / Fish Farms*

### 4.3 Source Description, Methodological issues and Data sources

#### 4.3.1 Data sources

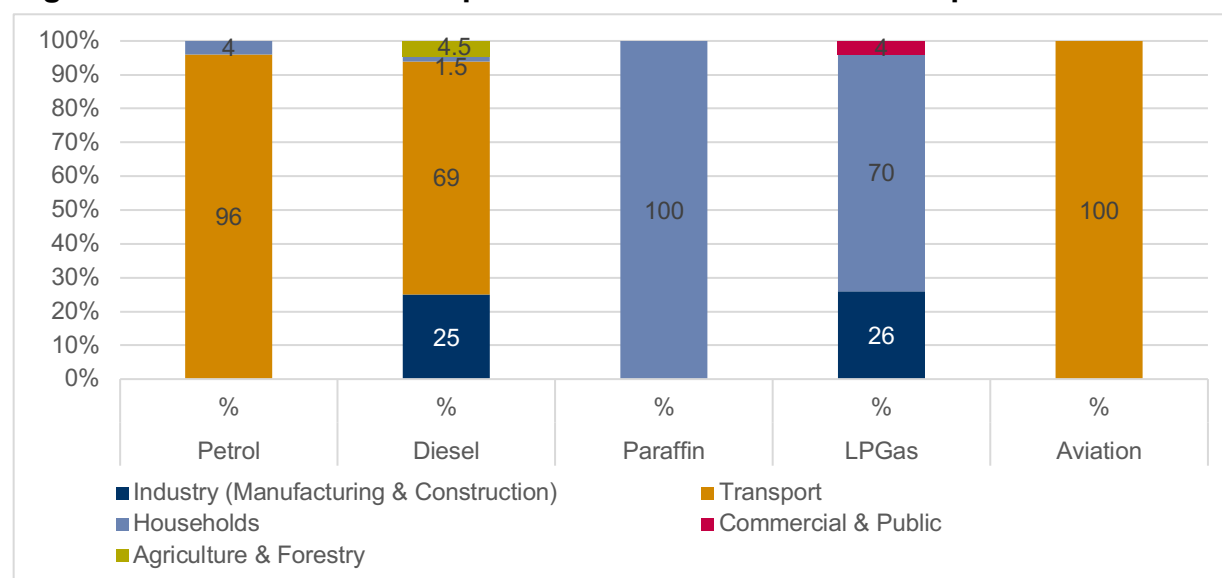
The only primary activity data used in the energy sector was the quantities of liquid fuels consumed per year. This data was provided by the Department of energy for all the liquid fuels imported and consumed in the country for each year between 1992 and 2018. But there were numerous gaps and inconsistencies in the data, hence additional data sources were sought, in the form of the 2015 Energy Report (Bureau of Statistics, 2017), and the 2017 Energy Report (Bureau of Statistics, 2018), which contain data up to 2014 and 2016 respectively. For the 2014, 2015 and 2016, the diesel and petrol data from the energy reports did not match the data from the Department of Energy, and in order to be conservative, the higher value was used in all cases. This was also the case for the 2014 - 2015 aviation fuel consumption values. For 2015 aviation fuel consumption, the energy reports also provided the ratio between consumption by Mission Aviation Fellowship and the military. This ratio was applied throughout the time series (2011 – 2017) to obtain total aviation fuel consumption in country for that period.

LPG values were only available for 2011 and 2014, hence the values for other years interpolated and extrapolated as necessary. Table 4-1 below shows the quantities of liquid fuels used in this GHG inventory for the years 2011 to 2017.

**Table 4-1 Litres of liquid fuels consumed in Lesotho from 2011 to 2017**

Year	Petrol	Diesel	Paraffin	LPG	Aviation gas
2011	101 914 000	77 140 000	37 542 000	5 005 000	64 138
2012	77 474 000	69 961 000	28 315 000	6 397 667	179 509
2013	76 345 000	70 795 000	27 240 000	7 790 333	336 269
2014	103 821 621	90 993 357	30 434 000	9 183 000	253 161
2015	115 748 600	97 542 590	28 930 000	10 575 667	280 832
2016	127 157 000	101 389 700	30 871 000	11 968 333	242 345
2017	133 335 000	78 231 000	33 621 000	13 361 000	396 272

The Department of Energy estimate that these fuels have generally been consumed in the various sectors as per Figure 4-1 below.

**Figure 4-1 Distribution of liquid fuels consumed in Lesotho per sector**

There are no statistics of solid fuels consumed in Lesotho, hence for this GHG inventory, these values were extrapolated by linear regression from the 2005 – 2010 consumption estimates made in the 3<sup>rd</sup> GHG inventory. Table 4-2 presents the estimated tonnes of solid fuels consumed in Lesotho between 2011 and 2017.

**Table 4-2 Tonnes of solid fuels consumed in Lesotho from 2011 to 2017**

Year	2011	2012	2013	2014	2015	2016	2017
Wood	693 348	705 888	718 428	730 968	743 508	756 048	768 588
Shrubs	644 042	655 592	667 142	678 692	690 242	701 792	713 342
Dung	630 007	641 426	652 845	664 264	675 683	687 102	698 521
Crop Residue	108 111	108 974	109 836	110 699	111 562	112 424	113 287
Coal	665 984	676 616	687 248	697 880	708 512	719 144	729 776

### 4.3.2 Conversions and emission factors

Table 4-3 and Table 4-4 below show net calorific values and the emission factors that were used for calculations of emissions in the energy sector respectively.

**Table 4-3 Net Calorific Values (NCV) used**

Fuel	NCV	Source
Aviation gas	33.9 MJ/L	(Department of Environmental Affairs, 2017)
Motor gasoline	34.2 MJ/L	(Department of Environmental Affairs, 2017)
Gas/Diesel oil	38.1 MJ/L	(Department of Environmental Affairs, 2017)
Other kerosene (paraffin)	37.5 MJ/L	(Department of Environmental Affairs, 2017)
LPG	25.6 MJ/L	(Department of Environmental Affairs, 2017)
Coal (Other bituminous)	24.3 MJ/kg	(Department of Environmental Affairs, 2017)
Fuelwood	19.32 MJ/kg	(Mosiori, et al., 2015)
Shrubs	19.18 MJ/kg	(Klein, 1986)
Crop residue	19,80 MJ/kg	(Klein, 1986)
Animal dung	14.0 MJ/kg	(Klein, 1986)

**Table 4-4 Default IPCC Emission Factors used in this inventory (IPCC, 2006)**

Type	Input	CO <sub>2</sub> (kg CO <sub>2</sub> /TJ)	CH <sub>4</sub> (kg CH <sub>4</sub> /TJ)	N <sub>2</sub> O (kg N <sub>2</sub> O/TJ)
Construction	Motor gasoline	69 300	3	0.6
	Gas/Diesel	74 100	3	0.6
Domestic aviation	Aviation gasoline	70 000	0.5	2
Road transport	Gas/Diesel oil	74 100	3.9	3.9
	Motor gasoline	69 300	33	3.2
Commercial/Institutional	Motor gasoline	69 300	10	0.6
	Other bituminous coal	94 600	10	1.5
	Liquefied petroleum gas	63 100	5	0.1

	Wood/wood waste	112 000	300	4
Residential	Motor gasoline	69 300	10	0.6
	Other kerosene	71 900	10	0.6
	Other bituminous coal	94 600	300	1.5
	Wood/wood waste	112 000	300	4
	Liquefied petroleum gas	63 100	5	0.1
Off-road vehicles and other machinery	Other primary solid biomass	100 000	300	4

### 4.3.3 Energy Industries (1A1)

The only energy industry in Lesotho is electricity generation. Electricity in Lesotho is generated from Muela's hydroelectric power station (72MW), and two mini hydro power plants in Semonkong and Mantšonyane (Bureau of Statistics, 2018). The rest of the electricity demand for Lesotho is met through purchased electricity from South Africa's Eskom. Therefore, there are no GHG emissions from energy industries.

### 4.3.4 Manufacturing Industries and Construction (1A2)

The three main industrial activities in Lesotho are mining and quarrying, construction and textile manufacturing. According to the Department of Energy, the industry sector in Lesotho primarily uses electricity, complemented by diesel and LPG as shown in Figure 4-1.

### 4.3.5 Transport (1A3)

In Lesotho, civil aviation and road transportation are the only two GHG-emitting categories in the transport sector.

#### 4.3.5.1 Civil Aviation (1A3a)

Civil aviation in Lesotho can be categorized into three types as follows:

1. **Commercial flights:** There are no longer domestic commercial flights operating in Lesotho. While a number of international airlines operate through Moshoeshoe I International Airport, none of them are fuelled in Lesotho, hence there are neither GHG emissions from domestic commercial flights nor international bunker emissions from international flights.
2. **Mission Aviation Fellowship (MAF) flights:** Since 1980, MAF has been operating 5 Cessna 206 aircrafts to transport the Lesotho Flying Doctor Service (LFDS) and other health and aid agencies operating in Lesotho's rural areas. In addition, MAF provides weekly flights to six health clinics operated by Partners-In-Health. In total, MAF serves 12 rural mountain health posts from over 20 dirt airstrips carved into the nation's rugged mountains (MAF website, 2019).
3. **The Lesotho Defence Force (LDF) Airwing:** This is located in the north-east of Maseru, and has three fixed-wing aircraft and six helicopters out of Mejametalana Airbase (Lesotho Review, 2018).

Emissions in this category come from the aviation gasoline combusted in MAF and LDF aircrafts.



**Figure 4-2 MAF plane taking off from the Mejametalana Airbase in Maseru East**



*Photo taken by Ewa Matuszewska, ERM, 2019.*

#### 4.3.5.2 Road Transportation (1A3b)

Lesotho's main transport network is road, which makes up 70% of domestic travel needs (Lesotho Review, 2018). The total national road network is in excess of 7,500 km in length, of which 1,526 km is tarred and the rest is gravel (3,036 km), earth (1,170 km), and tracks (132 km) (World bank PID, 2017).

**Figure 4-3 Photo showing infrastructure in Maseru**



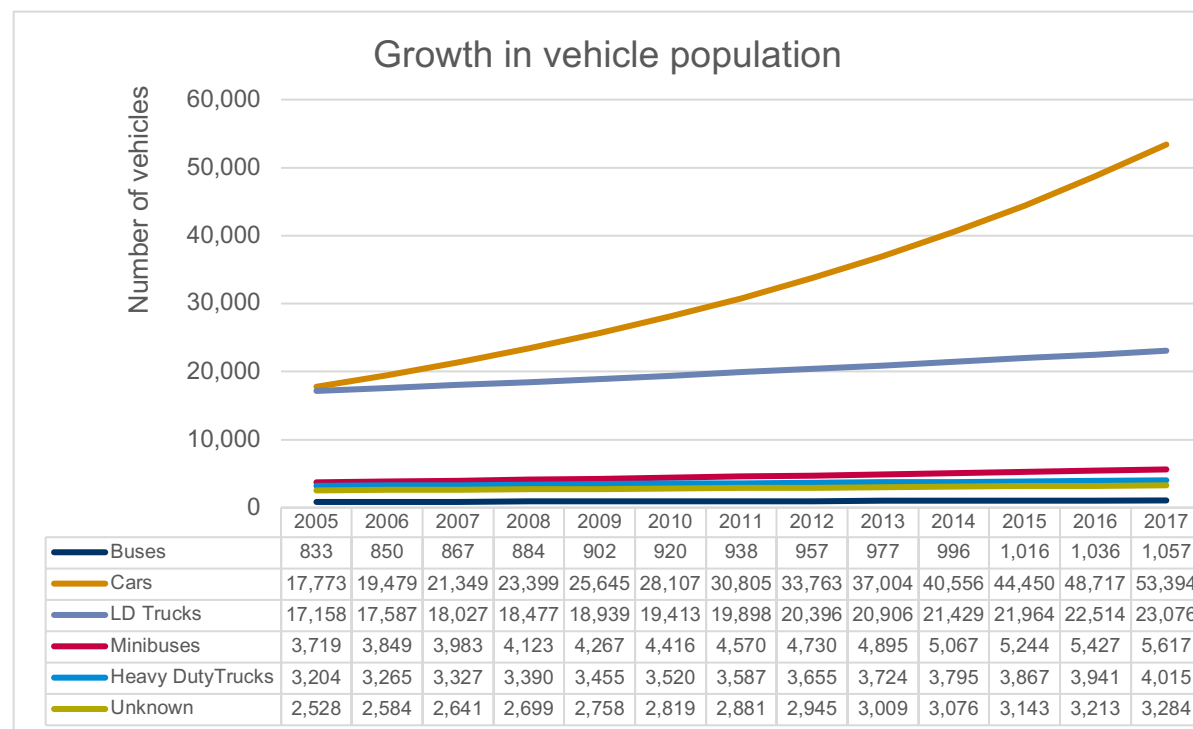
*Photo taken by Ewa Matuszewska, ERM, 2019.*

GHG emissions from this category are made up of carbon dioxide, methane and nitrous oxide emissions from the combustion of petrol and diesel in vehicles travelling on these roads.



The Department of Transport manages two databases of vehicles in the country, however it is not possible to extract information (numbers and types) on the annual population of vehicles in the country from these databases. As such, annual vehicle population was extrapolated from the 2005 – 2010 estimates made in the 3<sup>rd</sup> GHG inventory (LMS, 2018), using linear regression (Figure 4-4).

**Figure 4-4 Vehicle population between 2005 and 2017**



The GHG emissions in this category were estimated using Tier 2 approach. For each year the amount of greenhouse gas “g” emitted was calculated as per equation 1 below:

**Equation 1:**

$$GHG\ emissions_g = \sum_{f,v} (Population_{f,v} * Efficiency_{f,v} * Distance\ travelled_v * NCV_f * Emission\ factor_{f,g})$$

Where:

- $Population_{f,v}$  = annual population of vehicle type “v”, consuming fuel type “f”
- $Efficiency_{f,v}$  = fuel efficiency of vehicle type “v”, consuming fuel type “f” (litres/100km)
- $Distance\ travelled_v$  = annual average distance travelled by all vehicles of type “v” (km/vehicle)
- $NCV_f$  = Net Calorific Value of fuel type “f” (TJ/litre)
- $Emission\ factor_{f,g}$  = Default IPCC emission factor of gas “g” for fuel type “f” (Gg/TJ)
- $f$  = fuel type, which is either diesel or petrol.

The average distance travelled per mode of transport was determined based on the diesel and petrol consumption values in the transport sector as per Table 4-1 and Figure 4-1. Table 4-5

**Table 4-5 Estimated annual distance travelled per type of vehicle (km)**

Vehicle type	2011	2012	2013	2014	2015	2016	2017
Buses	26 637	20 990	20 162	25 744	27 138	27 971	21 825
Cars	17 645	11 429	10 230	13 165	13 755	14 242	15 515
LD Trucks	19 981	16 535	15 991	20 059	20 866	21 096	16 087
Minibuses	35 276	26 002	24 753	32 436	34 848	36 862	36 596
Heavy Duty Trucks	22 066	21 599	21 880	27 311	28 570	28 782	20 010
Unknown	900	900	900	900	900	900	700

The split between diesel and petrol vehicles for each type of vehicle were broadly based on Tongwane et al. (2015), with minor adjustments based on annual fuel consumption per type of fuel.

### 4.3.6 Other Sectors (1A4)

#### 4.3.6.1 Commercial / Institutional (1A4a)

This category covers emissions from fuel combustion in commercial and institutional buildings, particularly in commercial offices and public institutions, including government offices, prisons and schools. According to the Department of Energy, commercial and institutional buildings consume about 20% of all the solid fuels consumed in Lesotho and 4% of the LPG consumed in the country.

**Figure 4-5 Commercial and institutional sectors on the west side of Maseru**

Photo taken by Ewa Matuszewska, ERM, 2019.

#### 4.3.6.2 Residential (1A4b)

Included in this category are all the emissions from fuel combustion in households. The 2016 Population Census and household survey (Bureau of Statistics, 2018) shows that there were 537,457 households in Lesotho in 2016. The Census further indicates that LPG is the most popular fuel used for cooking in the country's urban areas (49.2%) while wood is the most common in the rural areas, used by 65.1% of rural households.

According to the Department of Energy, 80% of all the solid fuels used in the country are consumed in the residential sector, while the rest is consumed in the commercial and public sectors.

#### 4.3.6.3 Agriculture / Forestry / Fishing / Fish Farms (1A4c)

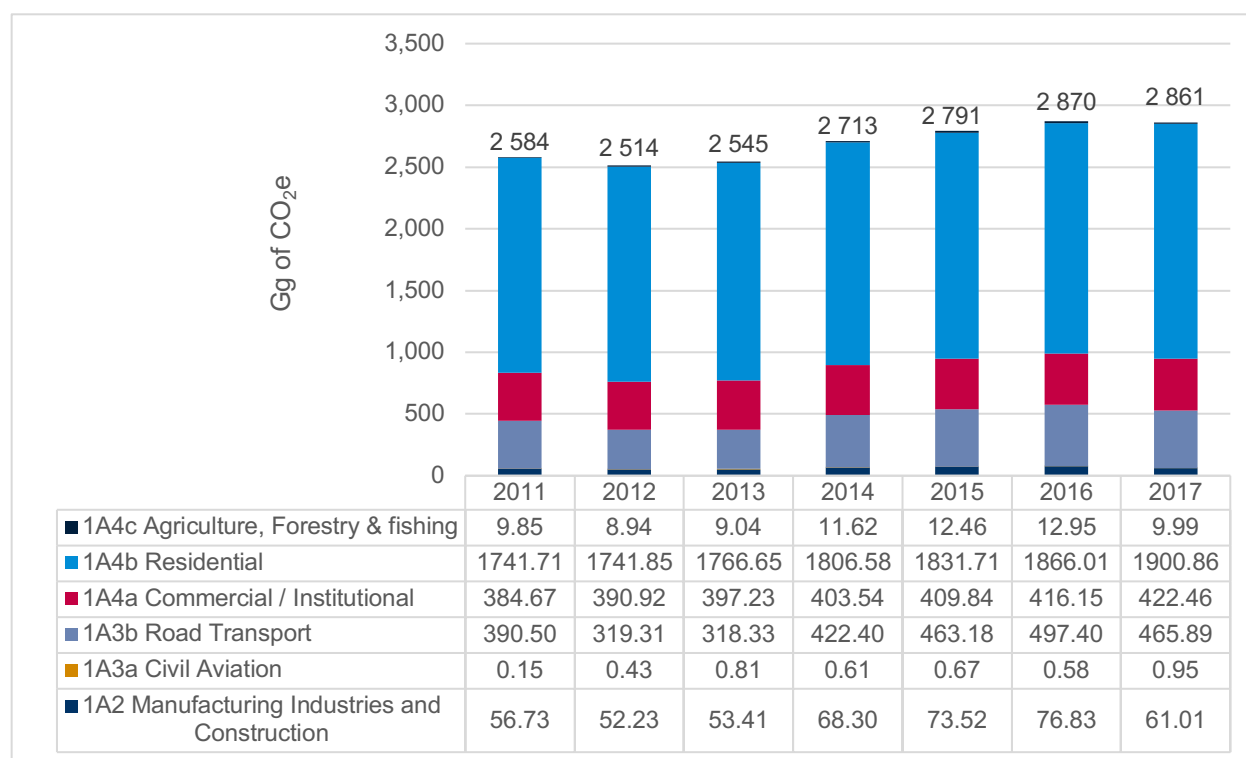
This covers the emissions from fuel combustion in agriculture, forestry and fishing industries. It includes stationary combustion emissions from these industries as well as emissions from off-road and traction vehicles used on farm land and in forests (IPCC, 2006). According to the Department of Energy, about 4.5% of the annual diesel consumption in the country is used by the agriculture, forestry and fishing industries.

### 4.4 Energy Sector GHG Emissions and Trends

Lesotho's GHG emissions from the energy sector amounted to 2,583.6 GgCO<sub>2</sub>e in 2011, and increased to 2,861.2 GgCO<sub>2</sub>e by 2017. Reduced consumption of diesel and petrol in 2012 and 2013 led to reduction in GHG emissions to 2,513.7 GgCO<sub>2</sub>e and 2,545.5 GgCO<sub>2</sub>e respectively. Overall, the emissions from the energy sector increased by 10.74% from 2011 to 2017.

Figure 4-6 presents the energy sector GHG emissions between 2011 and 2017, disaggregated by category.

**Figure 4-6 Energy Sector GHG emissions: 2011 - 2017**



The residential sector is the largest contributor to Lesotho's energy sector emissions accounting for 65.3% in 2016 (minimum) and 69.7% in 2013 (maximum), while civil aviation is the smallest contributor accounting for between 0.006% (in 2011) and 0.033% (in 2017).

#### 4.4.1 Manufacturing Industries and Construction (1A2)

Table 4-6 below presents the emissions from the manufacturing industries and construction, disaggregated by gas. The total emissions in this sector amounted to 56.73 Gg CO<sub>2</sub>e in 2011 and increased to 61.01 Gg

CO<sub>2</sub>e by 2017. Due to unavailability of disaggregated energy consumption data for each sector (construction, textile, etc.), it was also not possible to disaggregate the emissions.

**Table 4-6 Manufacturing Industries and Construction emissions**

Gas	2011		2012		2013		2014		2015		2016		2017	
	g	Gg CO <sub>2</sub> e	Gg	Gg CO <sub>2</sub> e	Gg	Gg CO <sub>2</sub> e	Gg	Gg CO <sub>2</sub> e	Gg	Gg CO <sub>2</sub> e	g	Gg CO <sub>2</sub> e	Gg	Gg CO <sub>2</sub> e
CO <sub>2</sub>	6.55	56.55	52.06	52.06	53.24	53.24	68.08	68.08	73.29	73.29	6.58	76.58	60.82	60.82
CH <sub>4</sub>	0.00	0.05	0.00	0.04	0.00	0.04	0.00	0.06	0.00	0.06	0.00	0.06	0.00	0.05
N <sub>2</sub> O	0.00	0.14	0.00	0.13	0.00	0.13	0.00	0.16	0.00	0.17	0.00	0.18	0.00	0.14
<b>Total</b>		<b>56.73</b>		<b>52.23</b>		<b>53.41</b>		<b>68.30</b>		<b>73.52</b>		<b>76.83</b>		<b>61.01</b>

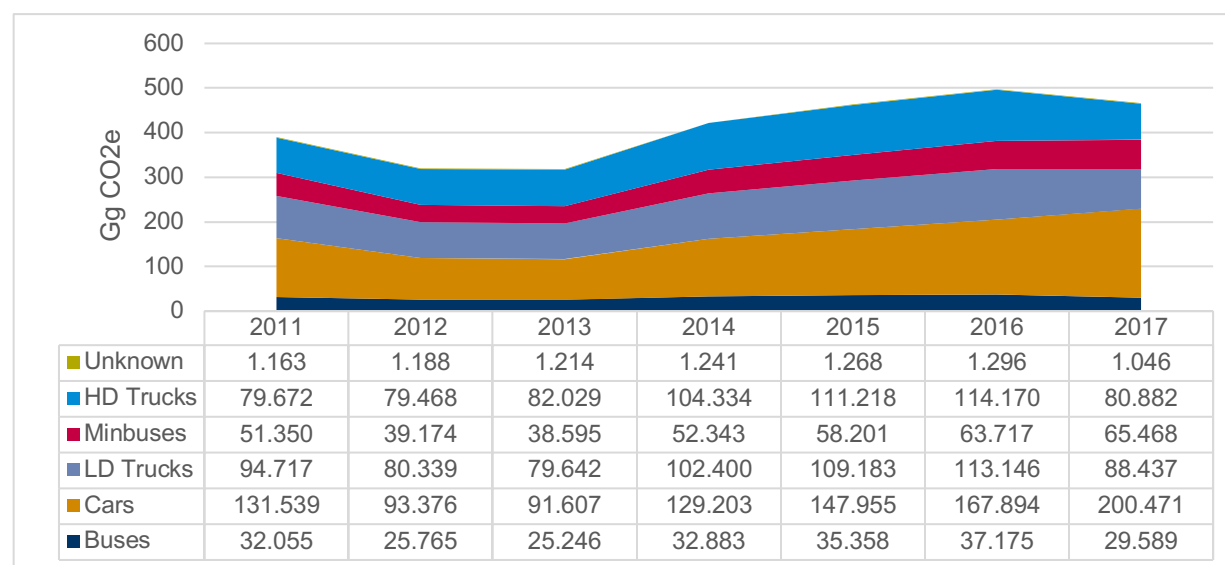
#### 4.4.2 Transport (1A3)

Table 4-7 show the trends in transport emissions between 2011 and 2017. Transport sector emissions were 390.65 Gg CO<sub>2</sub>e in 2011, increasing to 466.85 Gg CO<sub>2</sub>e in 2017. Road Transport accounted for over 99% of all the transport emissions throughout that period.

Figure 4-7 shows a disaggregation of the road emissions by vehicle type.

**Table 4-7 Transport sector emissions for 2011 – 2017, in Gg CO<sub>2</sub>e**

	2011	2012	2013	2014	2015	2016	2017
<b>1A3 Transport</b>	<b>390.65</b>	<b>319.74</b>	<b>319.14</b>	<b>423.01</b>	<b>463.86</b>	<b>497.98</b>	<b>466.85</b>
1A3a Civil Aviation	0.15	0.43	0.81	0.61	0.67	0.58	0.95
CO <sub>2</sub>	0.15	0.43	0.80	0.60	0.67	0.58	0.94
CH <sub>4</sub>	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N <sub>2</sub> O	0.00	0.00	0.01	0.01	0.01	0.01	0.01
1A3b Road Transport	390.50	319.31	318.33	422.40	463.18	497.40	465.90
CO <sub>2</sub>	382.15	312.56	311.61	413.48	453.37	486.82	455.77
CH <sub>4</sub>	2.57	2.00	1.98	2.65	2.94	3.21	3.30
N <sub>2</sub> O	5.77	4.75	4.74	6.27	6.87	7.36	6.83

**Figure 4-7 Road transport emissions disaggregated by vehicle type**

#### 4.4.3 Other Sectors (1A4)

GHG emissions from Other Sectors amounted to 2,126.4 Gg CO<sub>2</sub>e in 2011 and 2,323.3 Gg CO<sub>2</sub>e in 2017. The biggest contributor to these emissions is the residential sector, which accounts for about 82% of the emissions annually, followed by the commercial / institutional sectors at 18%. Table 4-8 shows the GHG emissions from the Other Sectors, disaggregated by gas.

**Table 4-8 Disaggregation of emissions from Other Sectors, in GgCO<sub>2</sub>e**

	2011	2012	2013	2014	2015	2016	2017
<b>1A4 Other Sectors</b>	<b>2 126.38</b>	<b>2 132.77</b>	<b>2 163.88</b>	<b>2 210.12</b>	<b>2 241.56</b>	<b>2 282.17</b>	<b>2 323.32</b>
1A4a Commercial / Institutional	384.67	390.92	397.23	403.54	409.84	416.15	422.46
CO2	326.93	332.23	337.53	342.84	348.14	353.45	358.75
CH4	46.98	47.80	48.62	49.44	50.26	51.07	51.89
N2O	10.76	10.89	11.08	11.26	11.45	11.63	11.82
1A4b Residential	1 741.71	1 741.85	1 766.65	1 806.58	1 831.71	1 866.01	1 900.86
CO2	1 426.22	1 421.15	1 440.61	1 475.11	1 494.89	1 523.80	1 553.25
CH4	272.36	276.90	281.51	286.17	290.78	295.42	300.06
N2O	43.14	43.80	44.53	45.30	46.04	46.79	47.55
1A4a Agriculture / Forestry / Fishing	9.85	8.94	9.04	11.62	12.46	12.95	9.99
CO2	9.80	8.89	8.99	11.56	12.39	12.88	9.94
CH4	0.03	0.03	0.03	0.03	0.04	0.04	0.03
N2O	0.02	0.02	0.02	0.03	0.03	0.03	0.02

## 4.5 Information items

According to the 2006 IPCC guidelines, emissions of CO<sub>2</sub> from biomass fuels (wood, dung, crop residues and shrubs) are estimated and reported in the AFOLU sector as part of the AFOLU methodology. To avoid double-counting, the CO<sub>2</sub> emissions from biomass fuels calculated in the energy sector are reported as information items only and not included in the sectoral or national totals. Table 4-9 presents the CO<sub>2</sub> emissions from biomass fuels for the period 2011 – 2017. The emissions were 3,585.32 Gg in 2011, reaching 4,233.53 Gg in 2017.

**Table 4-9 CO<sub>2</sub> emissions from biomass fuels, Gg**

	2011	2012	2013	2014	2015	2016	2017
Wood	1 500.29	1 527.43	1 554.56	1 581.70	1 608.83	1 635.97	1 663.10
Shrubs	988.96	1 257.43	1 279.58	1 301.73	1 323.88	1 346.04	1 368.19
Dung	882.01	898.00	913.98	929.97	945.96	961.94	977.93
Crop Residue	214.06	215.43	217.48	219.18	220.89	222.60	224.31
<b>TOTAL</b>	<b>3 585.32</b>	<b>3 898.28</b>	<b>3 965.60</b>	<b>4 032.58</b>	<b>4 099.56</b>	<b>4 166.55</b>	<b>4 233.53</b>

## 4.6 Uncertainty assessment

Uncertainty associated with energy data obtained from reliable energy balances and national energy statistics is about 5%. However, in this case, some of the data provided by the Department of Energy varied significantly with energy data published by the Bureau of Statistics. This increases the uncertainty associated with the petrol, diesel, LPG, illuminating paraffin and aviation data provided by the Department of Energy significantly. Expert judgment puts this uncertainty in the same range as uncertainty associated with energy data obtained through surveys in developing countries, which is 10 – 15%. Because consumption data for biomass fuels (wood, shrubs, dung and crop residues) as well as coal was estimated by extrapolation, it carries uncertainty in the range of 60 – 100% as per 2006 IPCC guidelines.

Combining these activity data uncertainties with uncertainties associated with the default emission factors applied to the different fuels results in the uncertainties presented in the table below:

**Table 4-10 Uncertainties associated with energy sector CO<sub>2</sub> emissions per fuel**

Fuel	Emission Factor Uncertainty (%)	Activity Data Uncertainty (%)	Combined Uncertainty (%)
Motor Gasoline	2.6 – 5.3	10 – 15	10.33 – 15.92
Aviation Gasoline	3.57 – 4.29	10 – 15	10.62 – 15.60
Other Kerosene	1.53 – 2.50	10 – 15	10.12 – 15.21
Diesel	0.94 – 2.02	10 – 15	10.04 – 15.14
Liquefied Petroleum Gas	2.38 – 3.94	10 – 15	10.28 – 15.51

## 4.7 Quality Assurance / Quality Control

Quality control was performed by the Energy team as per QC sheet, while data was being collected, when calculations were being performed and while the data was recorded in excel spreadsheets and the final numbers were added into the IPCC software. The following energy sector-specific QC activities were carried out:

- For liquid fuels, a full time series graph for each fuel, covering data for 1982 – 2017, was plotted to check and correct for data consistency;
- The 2012 – 2016 liquid fuels data obtained from the Department of energy was compared with the corresponding data published in the 2015 Energy Report and the 2017 Energy Report;
- Data and calculation checks were undertaken on the linear extrapolation calculations for vehicle statistics, biomass fuels and coal.
- Checks were also made on the application of fuel percentage splits per sector.

In addition, the ERM team performed additional checks and reviews on all the data, the calculations and the results, making corrections and improvements where necessary.

## 4.8 Recommendations for future improvements

There is need for strengthening of energy statistics in Lesotho in order to improve the accuracy of the energy sector GHG inventory. The following are the key recommended improvements:

- The compilation of a consistent accurate annual energy balance is recommended, based on actual energy consumption data
- Improving the accuracy of fossil fuel consumption data: All the fossil fuels used in Lesotho are imported from South Africa, and are by law required to be recorded when they enter the country. If the recording and monitoring procedures for imported fuels can be strengthened at the border gates by the Lesotho Revenue Authority, this would improve the accuracy and reliability of fossil fuel data in the country, and subsequently the accuracy of the GHG inventory.
- Strengthening the QC procedures for energy data management. It was observed that there were instances where the energy data held by the Department of Energy differed significantly with the data published by the Bureau of Statistics in energy reports. It is thus recommended that the quality control procedures as data is shared between different government institutions be strengthened.



## 5. INDUSTRIAL PROCESSES AND OTHER PRODUCT USE (IPPU)

### 5.1 An overview of the IPPU sector

Industrial activity in Lesotho is dominated by the textile industry which does not undertake activities that release industrial process emissions. The main industrial activity that results in industrial process emissions is the ceramic industry, which comprises of numerous brick-makers, ranging from large companies to individual producers using the large deposits of clay in Lesotho to manufacture bricks. The other, less significant contributor, in this category is the manufacture of beer by the Maluti Mountain Brewery. The use and disposal of refrigeration and air conditioning equipment is the main source of GHG emissions arising from product use in Lesotho.

#### Sources

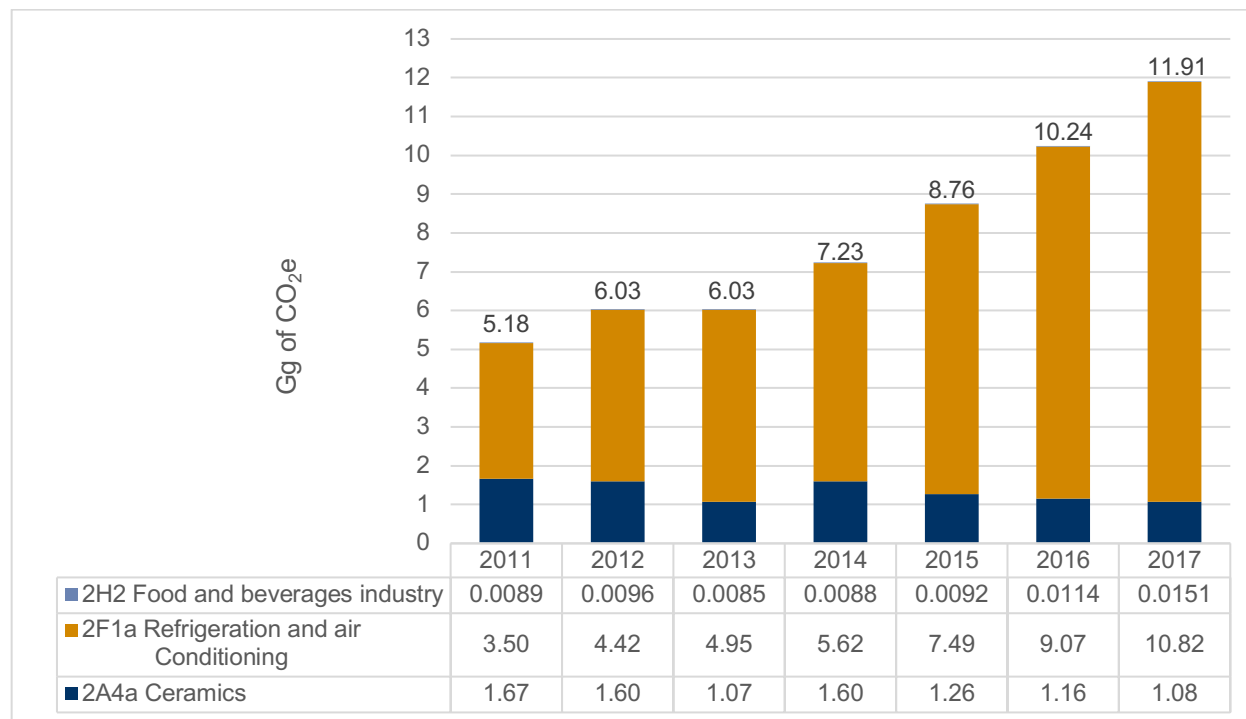
IPPU sector emissions in Lesotho come from the following categories:

- 2A4 Other Process Uses of Carbonates
  - 2A4a Ceramics
- 2F1 Refrigeration and Air Conditioning
- 2H2 Food and Beverages industry

### 5.2 IPPU Sector Emissions and Trends

Figure 5-1 below presents the totals and trends in GHG emissions for the IPPU sector for the years 2011 – 2017.

**Figure 5-1 Summary of the IPPU sector emissions for the years 2011 to 2017**



Between 2011 and 2017, IPPU sector GHG emissions increased by 130% from 5.18 Gg CO<sub>2</sub>e in 2011 to 11.92 Gg CO<sub>2</sub>e in 2017. Refrigeration and air conditioning are the largest contributors to emissions in this sector, with contributions ranging between 67.6% in 2011 to 90.8% in 2017. Food and beverages contribute the least to emissions in the IPPU sector, with contributions ranging between 0.1% and 0.2% throughout the period.

## 5.3 2A4a Ceramics

### 5.3.1 Source Description

The manufacture of ceramics falls within the mineral industry sector, under other process uses of carbonates. This category comprises the production of vitrified clay pipes, expanded clay products, technical ceramics, bricks and roof tiles, table and ornamental ware (household ceramics), refractory products, sanitary ware, wall and floor tiles and inorganic bonded abrasives. The process of calcination of carbonates in the clay and the addition of additives results in the emission of carbon dioxide gas. Ceramic products are primarily made from one or more different types of clay (e.g., shales, fire clay and ball clay).

In Lesotho there are widespread clay deposits all over the country and clay is utilised by small individual plaster brick producers and by local ceramic companies as raw materials for bricks. There is no database of all brick makers in the country.

**Figure 5-2 Informal fire clay brick-making in Maseru East**



*Photo taken by Ewa Matuszewska, ERM, 2019.*

Lesotho's bricks are manufactured from fire clay, coal additives are then used for colouring and to achieve the desired characteristics. The carbonates of dolomites and / or calcites are contained in fire clay deposits.

### 5.3.2 Data sources and Methodological issues

There are no statistics of clay consumption and brick manufacturing in Lesotho. In the past inventories the United States Geographical Survey (USGS) minerals Yearbooks, which report estimated clay consumption based on the installed capacity of Loti Brick – the largest brick manufacturer in the country. In this inventory, production data was first sources from Loti Brick, which could only provide data for 2015 – 17. This data was then complimented with data from the 2015 and 2016 USGS Yearbooks (USGS, 2016), which

contained data from 2012. Clay consumption for 2011 was calculated through linear extrapolation of the available 2012 – 2017 data.

Loti Brick supplied the number of bricks produced per year, together with the average weight 2.70 kg per brick, which is equivalent to the mass of clay used per brick. Hence, the tonnes of clay used per year was determined by multiplying the number of bricks per year with the weight per brick.

Table 5-1 below presents the tons of clay consumed between 2011 and 2017, disaggregated by source.

**Table 5-1 Quantify of clay consumed from 2011 – 2017, by data source**

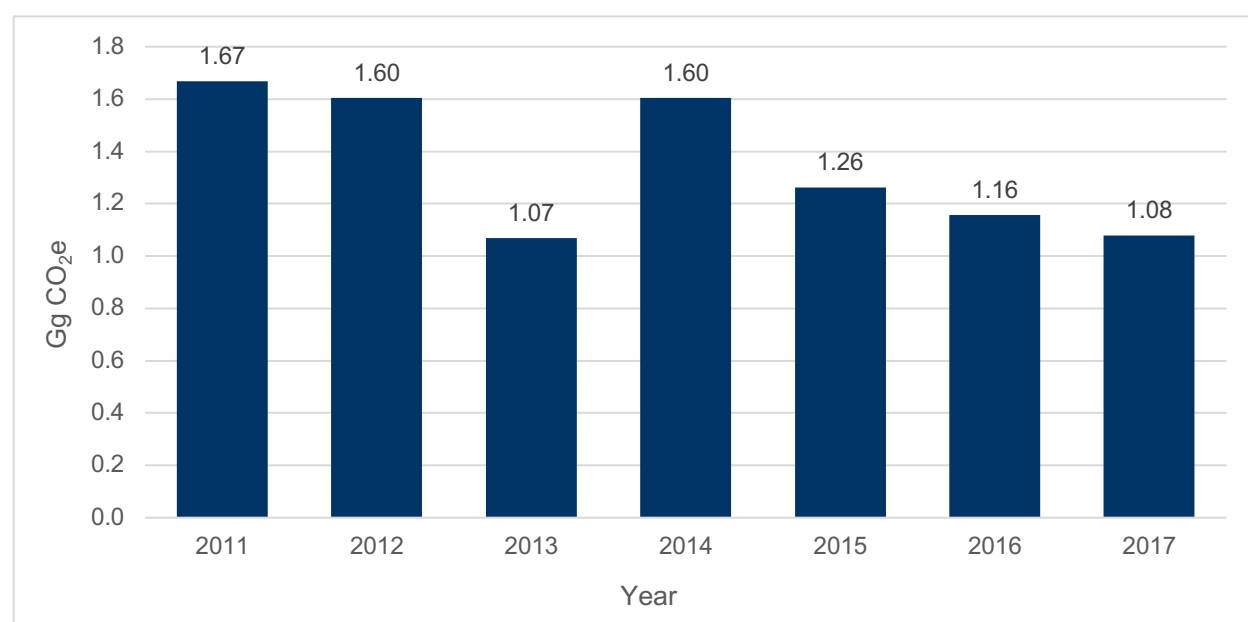
		2011	2012	2013	2014	2015	2016	2017
Tons of clay consumed		37 475	36 000	24 000	36 000	28 341	25 983	24 227
Data Source	U.S Geological Survey minerals yearbooks	Extrapolated	X	X	X			
	Loti brick					X	X	X

To calculate the emissions, a default 10% carbon content of clay was assumed, as well as an 85%:15% split between limestone and dolomite content in the clay as recommended in the 2006 IPCC guidelines. Default Tier 1 emission factors for limestone and dolomite were applied for emission estimates.

### 5.3.3 Results and Trends

Figure 5-3 below provides the GHG emissions for ceramics for the period 2011 – 2017 in Lesotho.

**Figure 5-3 Total emissions for ceramics in Lesotho from 2011 to 2017**



GHG emissions from the production of ceramics decreased from 1.67 Gg CO<sub>2</sub>e in 2011 to 1.08 Gg CO<sub>2</sub>e in 2017. This 35.4% decrease in emissions results from the overall reduction in the number of bricks produced. Emissions for the years 2011 – 2014 fluctuated yearly with a decrease of about 33% from 2012 to 2013 and about 50% increase from 2013 to 2014. Between 2014 and 2017 the emissions decreased by about 32%.

#### **5.3.4 Uncertainty assessment**

The uncertainty in this category lies in the uncertainty of the activity data since the emission factor based on the stoichiometric ratio reflecting the amount of CO<sub>2</sub> released upon calcination of the carbonate. The uncertainty of the activity data obtained from Loti Brick is very low (1 – 3 percent) because it is based on the actual production statistics. On the other hand, the activity data obtained from USGS has a higher uncertainty since it estimated based on historical production values and installed capacity. According to the 2006 IPCC guidelines, the uncertainty associated with the chemical analysis pertaining to carbonate content and identity also is 1-3 percent, while the uncertainty associated with the assumption of a default breakdown of limestone versus dolomite of 85%/15%, varies depending on country specific circumstances. A Lesotho-specific uncertainty analysis of the limestone: dolomite breakdown has not been done.

#### **5.3.5 Quality assurance / Quality control**

Quality control was performed by the IPPU team while data was being collected, when calculations were being performed and while the data was recorded in excel spreadsheets and the final numbers were added into the IPCC software. Hence, all the relevant points on the QC sheet were followed for emission calculations for ceramics.

In reference to quality assurance, ERM checked the quality of the inventory for ceramics and all the calculators and final numbers.

#### **5.3.6 Planned improvements and recommendations**

In order to improve the accuracy of the GHG emissions in this category, the following improvements are recommended:

- Improved data consistency over the entire time series: Currently the activity data over the time series is a combination of actual production data and production estimates based on capacity, and this affects the consistency of the emission estimates. It is thus recommended that a complete dataset of brick production be sourced from Loti brick for the entire time-series.
- Improved completeness: Ceramics in Lesotho are produced by many formal companies as well as companies and individuals in the informal sector. It is best practice to include all the sources of emissions for each category, hence it is recommended that a survey be undertaken to determine the full scale of brick production in the country.

## 5.4 2F1 Refrigeration and air conditioning

### 5.4.1 Source Description

Within the IPPU sector the product uses of substitutes for ozone depleting substances (ODS) can be broken down into refrigeration and air conditioning, foam blowing agents, fire protection, aerosols, solvents and other applications.

Refrigeration and air conditioning is the most prominent application in Lesotho. The use covers transport refrigeration, domestic refrigeration, stationary air conditioning including, commercial refrigeration and industrial processes including chillers, cold storage, and industrial heat pumps used in the food industry.

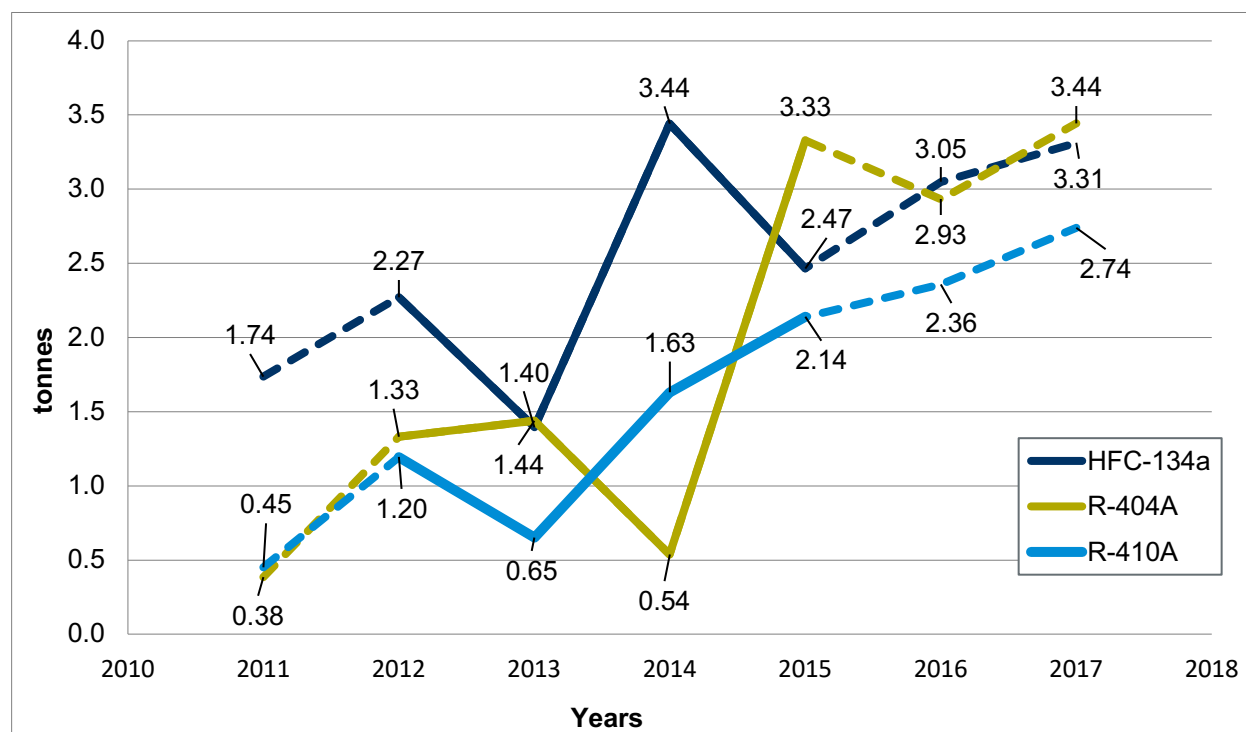
All refrigeration and stationary air conditioning equipment and refill gases are imported from South Africa. The biggest refrigeration and air conditioning ODS alternatives imported into Lesotho are HFCs. There are 19 main importing companies in Lesotho. There are over 100 different uses for these gases in Lesotho.

### 5.4.2 Data Sources and Methodological issues

The data for HFCs consumed in the country between 2012 and 2015 was provided by the Ozone Unit of the Lesotho Meteorological Services. The data comprised consumption of pure HFC-134a and of HFC blends R-404A (44% HFC-125, 52% HFC-143a and 4% HFC-134a) and R-410A (50% HFC-32, 50% HFC-125). HFC consumption for the years 2011, 2016 and 2017 was projected from the 2012 – 2015 data using linear regression.

Figure 5-4 below presents the actual and projected consumption of pure HFC-134a for the period 2011 – 2017.

**Figure 5-4 Consumption of pure HFC-134a and HFC blends between 2011 and 2017\***



\*Dotted lines in the graph depict projected data

The resulting annual consumption of each individual HFC gas for the period 2011 – 2017 is shown in Table 5-2 below.

**Table 5-2 Quantity of individual HFC gases consumed between 2011 and 2017**

	2011	2012	2013	2014	2015	2016	2017
HFC - 134a	1.75	2.32	1.45	3.46	2.60	3.17	3.45
HFC - 125	0.39	1.18	0.96	1.05	2.54	2.47	2.89
HFC - 143a	0.20	0.69	0.75	0.28	1.73	1.53	1.79
HFC - 32	0.23	0.60	0.33	0.82	1.07	1.18	1.37

To estimate the annual emissions, the default 2006 IPCC guideline method, with the parameters shown in Table 5-3 below, was used.

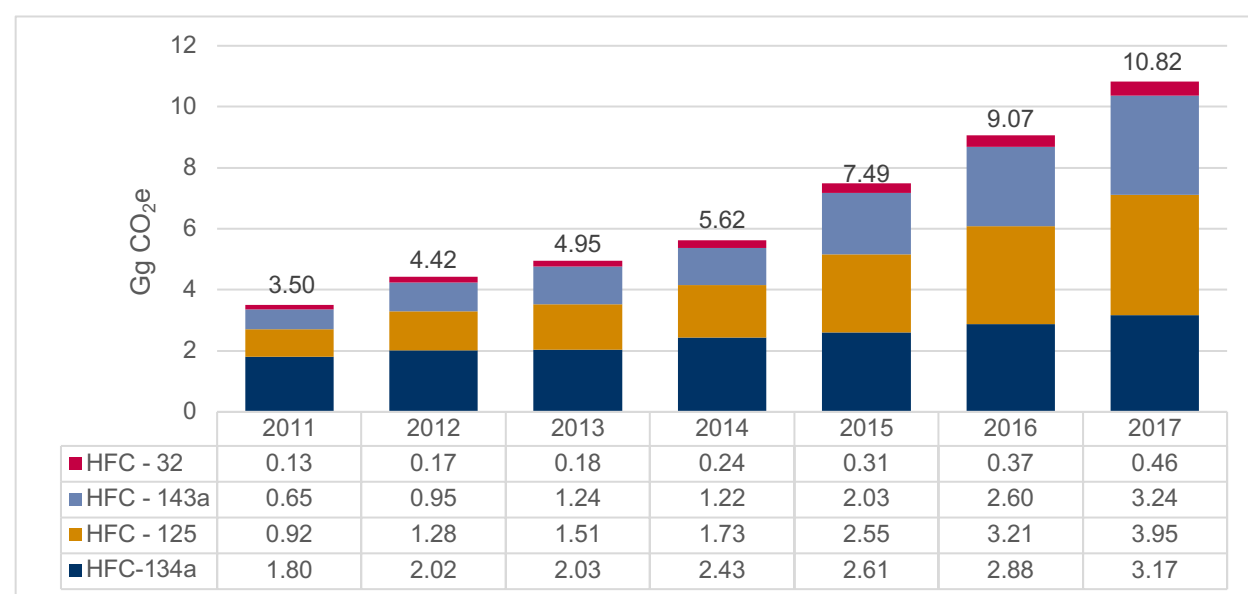
**Table 5-3 Parameters used to estimate annual emissions of HFCs from refrigeration and air conditioning equipment**

	Introduction year	Annual growth rate	Equipment lifetime	Emitted gas %	Destroyed gas %
Value and units	1993	1%	15 years	15%	0%

### 5.4.3 Results and Trends

Figure 5-5 below provides the annual emission estimates of HFCs from refrigeration and stationery air conditioning for the time series of 2011 to 2017 in Lesotho.

**Figure 5-5 HFC emissions from refrigeration and air conditioning from 2011 to 2017**





Refrigeration and stationary air conditioning emissions in Lesotho have increased three-fold between 2011 and 2017, from 3.50 Gg CO<sub>2</sub>e in 2011 to 10.82 Gg CO<sub>2</sub>e in 2017. In 2011 HFC-134a was the largest contributor of GHG emissions at 51.5%, followed by HFC-125 and HFC-143a with 26.2% and 18.6% respectively. Over the six years, however, emissions of HFC-125 and HFC-143a have been growing faster than those of HFC-134a reaching 36.6% and 29.9% of the total HFC emissions by 2017 respectively. This is as a result of the relatively higher growth in the use of equipment using R-404A and R-410A compared to those using pure HFC-134a.

#### **5.4.4 Uncertainty assessment**

GHG emissions from this category have been estimated for the first time in this 4th GHG inventory, as such it is difficult to quantify the level of uncertainty due to the large number of emission patterns. In general, the uncertainty of the activity data depends on the accuracy with which the quantity of HFCs consumed annually has been determined. If this data is collected directly from the importers the uncertainty associated with it will be very low. The greatest uncertainty for this category lies in the emission factors, including the annual growth rate, the equipment lifetime and the percentage of gas emitted over time, especially if the activity data has not been disaggregated by sub-application as is the case for this inventory. According to the 2006 IPCC guidelines, equipment lifetime ranges between 6 and 30 years, while emission factor percentages range between 0.2% and 50%. Because the bulk of HFCs in Lesotho are used in domestic refrigeration and stand-alone commercial applications, conservative default values for both equipment lifetime and emission factor percentages have been applied.

#### **5.4.5 Quality assurance/ Quality control**

Quality control was performed by the IPPU team for this category while data was being collected when calculations were being performed and while the data was recorded in excel spreadsheets and the final numbers were added into the IPCC software. Internal QC included checking the units of the HFC activity data as received from the Ozone Unit, ensuring consistent time-series of HFC quantities, checking that the percentages of individual HFCs contained in each of the HFC blends (R-401A and R-410A) have been correctly recorded and applied to the blends, accuracy in transferring the data onto the IPCC software and accuracy in applying the correct emission parameters.

The ERM then reviewed the data, all the calculators and final numbers and assured the overall quality of the inventory for refrigeration and stationary air conditioning.

#### **5.4.6 Planned improvements and recommendations**

For the refrigeration and air conditioning category, the following improvements are recommended:

- To ensure completeness and a consistent time series, it is recommended that an accurate inventory of all new refrigerators and air condition units imported into the country be kept and included in future inventories. For accuracy of the inventory this data needs to be disaggregated by sub-application (e.g. mobile refrigeration, etc.)
- To ensure a consistent time series going back, it is recommended that BOS assists with surveys and/or collect information on existing units (refrigerators and AC), particularly in all shops, disaggregated by sub-application, name of ODS substance, quantity of ODS substance, year of introduction and year of import.
- BOS has started including questions related to the use of fridges and air-conditioning systems in their regular planned household surveys; it is recommended that these questions be tailored to ensure that as much data required for the GHG inventory is gathered through these surveys.



## 5.5 2H2 Food and beverages industry

### 5.5.1 Source Description

Non-Methane Volatile Organic Compounds (NMVOCs), which are precursors to greenhouse gases, are produced during the processing of cereals and fruits when manufacturing fermented foods and beverages (IPCC, 1996). Lesotho has a relatively small food and beverages industry. The country imports most of its food products and beverages from South Africa. Between 2015 and 2017 the food products and beverages industry in Lesotho has effectively grown by M3.25 million, and it is expected to grow by between M0.59 million and M0.70 million between 2019 and 2020 (Central Bank of Lesotho, 2018). The country's sole brewery, Maluti Mountain Breweries, produces the local Maluti Premium lager, in addition to other international beer brands.

### 5.5.2 Data Sources and Methodological issues

Amount of beer produced in 2016 and 2017 was provided by Maluti Mountain Breweries. The company could not provide production data for earlier years because their database had changed in 2016 and therefore were not able to retrieve the earlier data. Data for 2011 – 2015 was therefore extrapolated using linear regression. Table 5-4 below shows the amount beer produced in 2016 and for each of the five beer brands, as well as the extrapolated total beer production for the period 2011 – 2015.

**Table 5-4 Amount of beer in 2016 and 2017 in hecta-litres**

Brand	2011	2012	2013	2014	2015	2016	2017
Castle Lager						125 613	180 891
Maluti Premium Lager						60 517	85 883
Carling Black Label						66 115	91 976
Hansa						43 704	39 832
Milk Stout						28 765	33 471
<b>Total</b>	<b>253 315</b>	<b>273 854</b>	<b>242 556</b>	<b>251 359</b>	<b>263 096</b>	<b>324 713</b>	<b>432 052</b>

To estimate the GHG emissions, a default emission factor of 0.035kg/HL, obtained from the Revised 1996 IPCC guidelines, was then applied.

### 5.5.3 Results and Trends

Table 5-5 below presents estimated NMVOC emissions from the food and beverages industry for the time series of 2011 - 2017 in Lesotho. The emissions were 0.0089 Gg in 2011 and then increased by 70.5% percent to 0.0151 by 2017.

**Table 5-5 Gg of NMVOC emissions from food and beverages industry from 2011 to 2017**

2H Other	2011	2012	2013	2014	2015	2016	2017
<b>2H2 Food and Beverages Industry</b>	<b>0.0089</b>	<b>0.0096</b>	<b>0.0085</b>	<b>0.0088</b>	<b>0.0092</b>	<b>0.0114</b>	<b>0.0151</b>
Beverages	0.0089	0.0096	0.0085	0.0088	0.0092	0.0114	0.0151

#### 5.5.4 Uncertainty assessment

One of the aspects of uncertainty in food and beverages industry is that due to the lack of time series because data was only available for two years and the data for the other years had to be extrapolated and based on the two years. For good extrapolation of data, there should ideally be three or more data to extrapolate from, but unfortunately there was only data for two years from Maluti Mountain Breweries (MMB). The actual activity data obtained from MMB has very little uncertainty as it was obtained directly from the brewery which is deemed to keep accurate production data.

#### 5.5.5 Quality assurance/ Quality control

Quality control was performed by the IPPU team while data was being collected, when calculations were being performed and while the data was recoded in excel spreadsheets and the final numbers were added into the IPCC software. Specific QC checks included checks that the data from MMB was accurately recorded onto the spreadsheets, extrapolation of the activity data was done correctly, both activity data and the correct emission factors were used in the IPCC software and that the results were accurately reported.

The ERM team then reviewed the data, the calculations and the results to ensure the quality of the inventory for the food and beverages industry.

#### 5.5.6 Planned improvements and recommendations

In order to improve the quality of the food and beverages inventory, it is recommended that:

- A complete set of data from Maluti Mountain Breweries be requested well before the next GHG inventory is compiled, in order to build a consistent and complete data series. The latter would also require recalculations of the emissions for this category for those historical years for which activity data was not available.
- LMS signs a Memorandum of Understanding with the data providers before next GHG inventory is compiled, in order to build a complete and consistent data series.

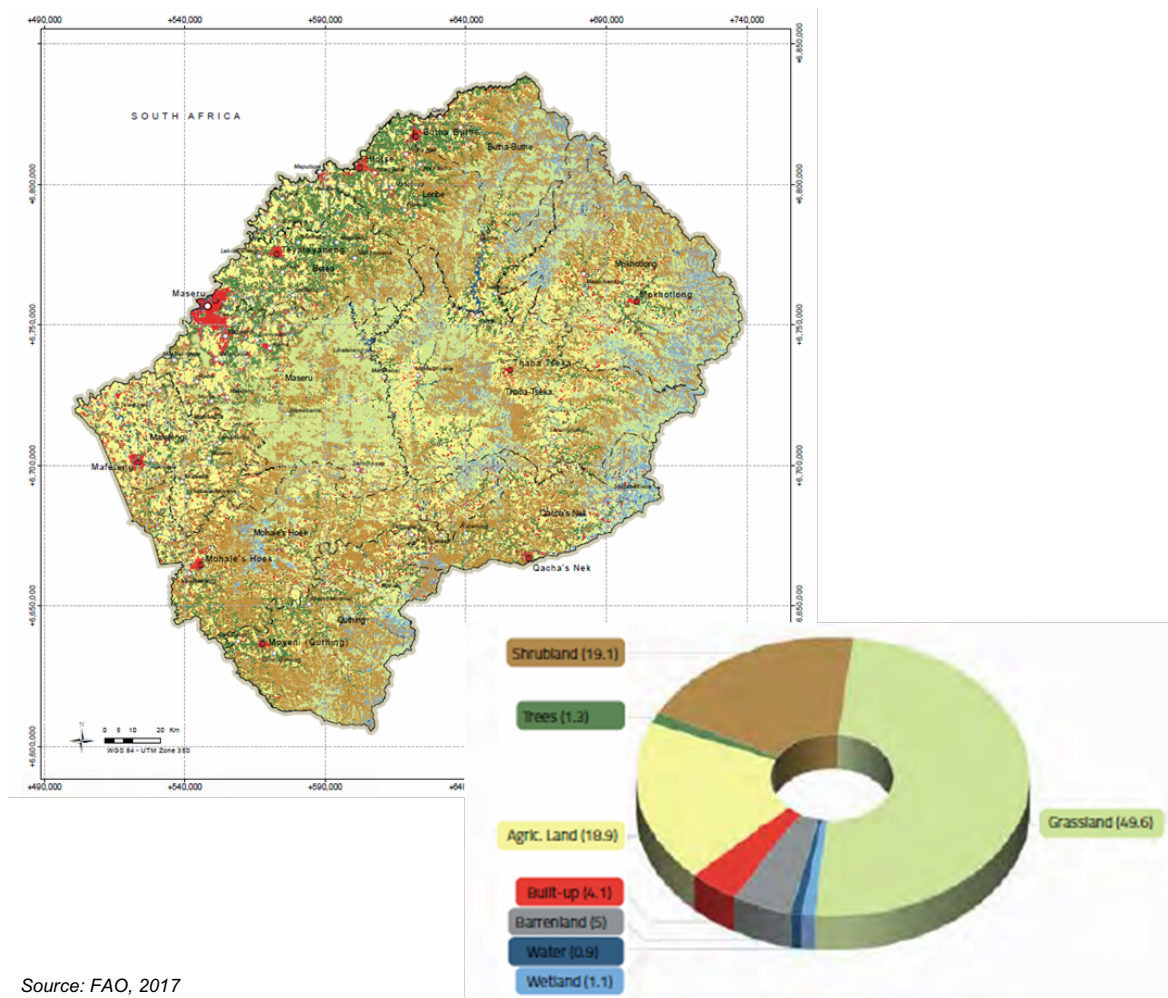
## 6. AGRICULTURE, FORESTRY AND OTHER LAND USE (AFOLU)

### 6.1 An overview of the AFOLU sector

In reference to AFOLU, land use and management effect a variety of ecosystem processes that affect greenhouse gas changes, these include: respiration, photosynthesis, decomposition, combustion, enteric fermentation and nitrification/denitrification. These processes comprise transformations of carbon and nitrogen that are driven by the biological and physical processes. The key greenhouse gases in AFOLU are CO<sub>2</sub>, N<sub>2</sub>O and CH<sub>4</sub>.

The GHG emissions from the agriculture, forestry and other land-use (AFOLU) sector often have the highest contribution in developing countries because of their reliance on agriculture. Lesotho, like all other least developed countries, has majority of her population relying on agriculture for livelihood. Agricultural land covers 18.9% of Lesotho, while grasslands cover 49.6% (**Error! Reference source not found.**). Trees and shrubs cover 1.3% and 19.1% respectively.

**Figure 6-1 Land cover map and summary of the land cover statistics of Lesotho**



Source: FAO, 2017

Farming is an important livelihood activity for a significant percentage of the population due to the fact that about 70% of Lesotho's people live in rural areas (Lesotho Review, 2018).

### *Agriculture in Lesotho*

Agriculture still remains the main source of livelihoods in terms of food and income. The agricultural sector alone is responsible for employing 65% of the population mainly in the rural areas. In terms of income, 77% of household income was derived from farming in 2014 (BOS, 2014).

Crop production is mainly rain fed, with a few and small irrigation schemes covering about 1 358 hectares of the total arable land countrywide. As a result, Lesotho is more susceptible to drought and desertification. Lesotho's main crops grown by mostly subsistence farmers are maize, wheat, sorghum and drybean (BOS, 2017a). Horticulture in the country is characterized by fruit and vegetable production through homestead gardens, community gardens and backyard fruit trees.

Rangelands cover around 50% of Lesotho and support the large amount of livestock present in Lesotho. National livestock statistics (BOS, 2018) indicates that there are around 4 million livestock in Lesotho, with approximately 50% of this being sheep and 25% goats. Livestock are reared for production of meat, wool, skins, mohair, hides, manure, drawing carts and ploughing.

**Figure 6-2 Photo of cattle used to draw a cart in Lesotho**



Source: Shutterstock

## Forestry in Lesotho

Forests account for a very small percentage of Lesotho but indigenous trees and shrubs coverage is more significant (Figure 6.1). Lesotho's very small area of tree plantations comprises exotic species, and are of two types. The first category of plantations are those grown primarily for wood production (mainly Government-owned woodlots), and the second comprises those planted by the present and past Governments mainly for erosion stabilisation but self-regenerating and now regularly harvested by rural people for firewood and poles (FAO, 2014). Forestry in Lesotho contributes insignificantly to the official revenue figures in the national economy. The greatest threat by far to forest resources in Lesotho is from the browsing of the re-growth of harvested woody plants by its huge population of freely-grazed domestic livestock (FAO, 2014).

## Key categories

The key categories for the AFOLU sector from the 2010 key category analysis for all three gases was:

- 3A1 Enteric fermentation;
- 3A2 Animal Waste Management Systems;
- 3C1 Prescribed burning of savannas;
- 3C4 Direct emissions from agricultural soils;
- 3C5 Indirect emissions from agricultural soils.

## Completeness

Liming (3C2) was excluded from AFOLU as there was insufficient data on lime consumption to include this category. Data was only available for the year 2013 and it is unclear how reliable this data is.

## Sources

This section includes GHG emissions and removals from agriculture as well as land use and forestry. Based on the IPCC 2006 Guidelines, the following categories were included in this inventory:

- Livestock:
  - 3A1 Enteric fermentation;
  - 3A2 Manure management;
- Land:
  - 3B1 Forest land;
- Aggregate sources and non-CO<sub>2</sub> emissions on land:
  - 3C1 Biomass burning;
  - 3C3 Urea application;
  - 3C4 Direct N<sub>2</sub>O emission from managed soils;
  - 3C5 Indirect N<sub>2</sub>O emission from managed soils;



- 3C6 Indirect N<sub>2</sub>O emission from manure management.

Emissions from fuel combustion in this sector are not included here as these fall under the agriculture/forestry/fisheries subsector in the energy sector. Losses of CO<sub>2</sub> emissions from biomass burning are included under losses due to disturbance in the land section (3B) and not in the biomass burning (3C1) section. Section 3C1 deals with non-CO<sub>2</sub> emissions from biomass burning in all land use types.

### Methodology and Completeness

**Error! Reference source not found.** provides a summary of the methods and types of emission factors used during the compilation of this inventory. All estimates were made via the use of the IPCC 2006 inventory software.

**Table 6-1 Summary of methods and emission factors for the AFOLU sector and an assessment of the completeness of the AFOLU sector emissions<sup>1</sup>**

GHG Source and sink category	CO <sub>2</sub>		CH <sub>4</sub>		N <sub>2</sub> O	
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
<b>A Livestock</b>						
<b>Enteric fermentation</b>						
a.i. Dairy cattle	NA		T1	DF	NA	
a.ii. Other cattle	NA		T1	DF	NA	
b. Buffalo	NA		NO		NA	
c. Sheep	NA		T1	DF	NA	
<b>1</b> d. Goats	NA		T1	DF	NA	
e. Camels	NA		NO		NA	
f. Horses	NA		T1	DF	NA	
g. Mules and asses	NA		T1	DF	NA	
h. Swine	NA		T1	DF	NA	
j. Other (Game)	NA		NE		NA	
<b>Manure management</b>						
<b>2</b> a.i. Dairy cattle	NA		T1	DF	T1	DF
a.ii. Other cattle	NA		T1	DF	T1	DF
b. Buffalo	NA		NO		NO	

<sup>1</sup> NA = Not applicable; NE = Not Estimated; NO = Not Occurring; DF = Default Factor; T1 = Tier 1

	c. Sheep	NA		T1	DF	T1	DF
	d. Goats	NA		T1	DF	T1	DF
	e. Camels	NA		NO		NO	
	f. Horses	NA		T1	DF	T1	DF
	g. Mules and asses	NA		T1	DF	T1	DF
	h. Swine	NA		T1	DF	T1	DF
	i. Poultry	NA		T1	DF	T1	DF
	j. Other (Game)	NA		NE		NE	
<b>B</b>	<b>Land</b>						
	<i>Forest land</i>						
<b>1</b>	a. Forest land remaining forest land	Biomass: T1	Biomass: DF	NE		NE	
		DOM: NE					
		Soil: NE					
	b. Land converted to forest land	Biomass: NE		NE		NE	
		DOM: NE					
		Soil: NE					
	<i>Cropland</i>						
<b>2</b>	a. Cropland remaining cropland	Biomass: NE		NE		NE	
		DOM: NE					
		Soil: NE					
	b. Land converted to cropland	Biomass: NE		NE		NE	
		DOM: NE					
		Soil: NE					
	<i>Grassland</i>						
<b>3</b>	a. Grassland remaining grassland	Biomass: NE		NE		NE	
		DOM: NE					
		Soil: NE					
	b. Land converted to grassland	Biomass: NE		NE		NE	
		DOM: NE					
		Soil: NE					
	<i>Wetland</i>						
<b>4</b>	a. Wetland remaining wetland	NE		NE		NE	
	b. Land converted to wetland	NE		NE		NE	



Settlements							
5	a. Settlements remaining settlements	Biomass: NE		NE		NE	
		DOM: NE					
		Soil: NE					
	b. Land converted to settlements	Biomass: NE		NE		NE	
		DOM: NE					
		Soil: NE					
Other land							
6	a. Other land remaining other land	Biomass: NE		NE		NE	
		Soil: NE					
	b. Land converted to other land	Biomass: NE		NE		NE	
		Soil: NE					
C Aggregated sources and non-CO <sub>2</sub> emissions on land							
1	Biomass burning	T1	DF	T1	DF	T1	DF
2	Liming	NE		NA		NA	
3	Urea application	T1	DF	NA		NA	
Direct emissions from managed soils							
4	Synthetic fertilizers	NA		NA		T1	DF
	Animal waste added to soils	NA		NA		T1	DF
	Other organic fertilizers	NA		NA		T1	DF
	Urine and dung deposited by grazing livestock	NA		NA		T1	DF
	Crop residues	NA		NA		T1	DF
Indirect emissions from managed soils							
5	Atmospheric deposition	NA		NA		T1	DF
	Nitrogen leaching and runoff	NA		NA		T1	DF
Indirect emissions from manure management							
6	Volatilization	NA		NA		T1	DF
	Nitrogen leaching and runoff	NA		NA		NE	
7	Rice cultivation	NO		NO		NO	
D Other							
1	Harvested wood products	NE		NA		NA	

## 6.2 Results and Trends in AFOLU

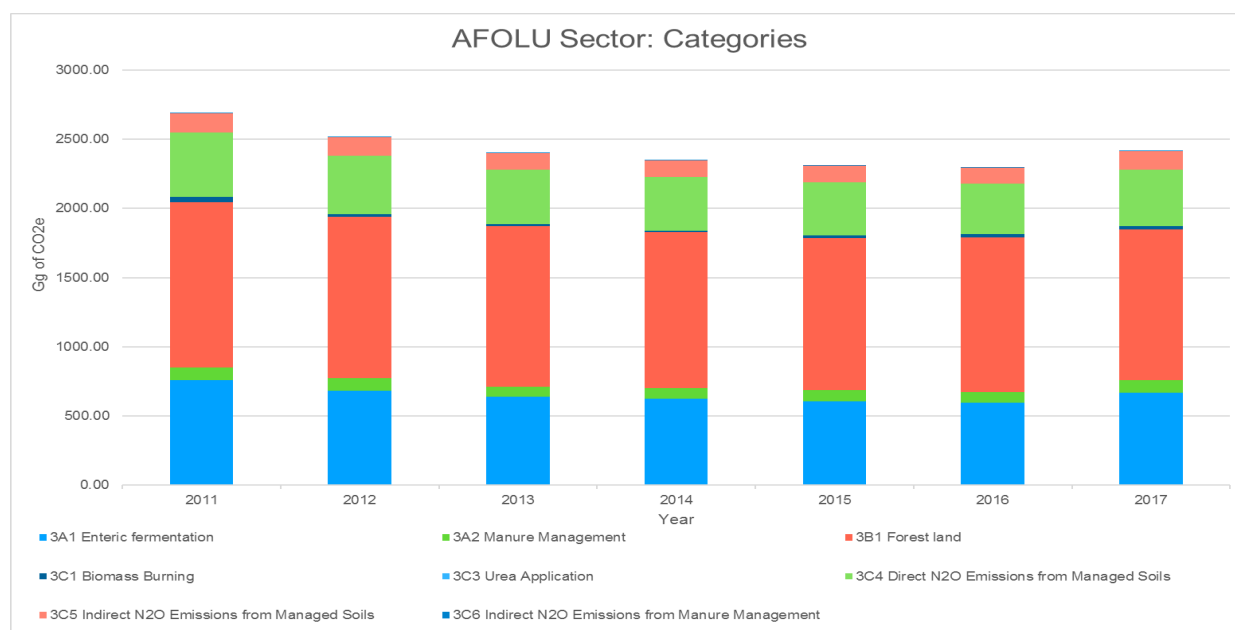
**Error! Reference source not found.** below demonstrates the totals in Gg of CO<sub>2e</sub> emissions for the AFOLU sector for the years 2011 to 2017.

**Table 6-2 Summary of the AFOLU sector emissions, in Gg CO<sub>2e</sub>, for the years 2011 until 2017**

AFOLU Sector	2011	2012	2013	2014	2015	2016	2017
3A1 Enteric fermentation	761.19	684.94	638.50	625.25	608.04	594.30	669.65
3A2 Manure Management	90.22	89.09	75.17	76.74	81.25	78.65	87.95
3B1 Forest land	1193.64	1164.86	1156.50	1124.71	1097.58	1117.23	1089.55
3C1 Biomass Burning	36.65	19.05	15.60	11.98	17.66	23.73	23.73
3C3 Urea Application	0.08	0.08	0.12	0.07	0.05	0.08	0.08
3C4 Direct N <sub>2</sub> O Emission from Managed Soils	465.86	423.85	394.31	390.29	382.35	364.69	408.85
3C5 Indirect N <sub>2</sub> O Emission from Managed Soils	140.59	131.84	121.49	120.01	119.28	114.07	135.11
3C6 Indirect N <sub>2</sub> O Emissions from Manure Management	2.18	2.21	1.76	1.68	1.99	1.77	2.05
<b>Totals</b>	<b>2690.41</b>	<b>2515.92</b>	<b>2403.44</b>	<b>2350.74</b>	<b>2308.19</b>	<b>2294.52</b>	<b>2416.97</b>

The below graph (**Error! Reference source not found.**) provides the illustration of the above graph for the Gg of CO<sub>2e</sub> emissions in Lesotho by each sub-sector for the AFOLU sector over the years 2011 to 2017.

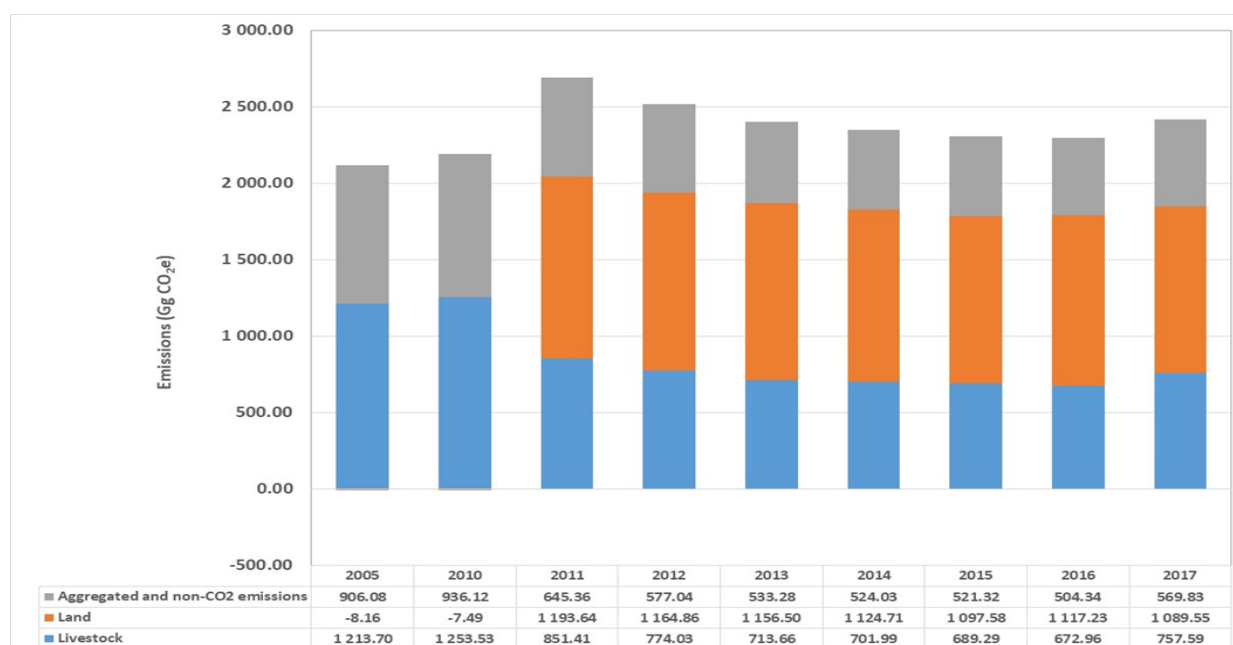
**Figure 6-3 Graph showing the AFOLU sector totals by sub-sector**



### Trends

The AFOLU sector is estimated to produce 2 417 Gg CO<sub>2</sub>e in 2017. Emissions declined from 2012 to 2016, and then increased slightly in 2017. The land sector is the largest contributor (45.1%), followed by livestock (**Error! Reference source not found.**). The emission estimates are higher than what was provided in the previous inventory (2005 to 2010) (LMS, 2018), however there are inconsistencies in the data sources and some methodologies, therefore the change is representative of these changes not actual emission changes. The reason for these inconsistencies as discussed in the sections below.

**Figure 6-4 Summary of GHG emission trends in the AFOLU sector**

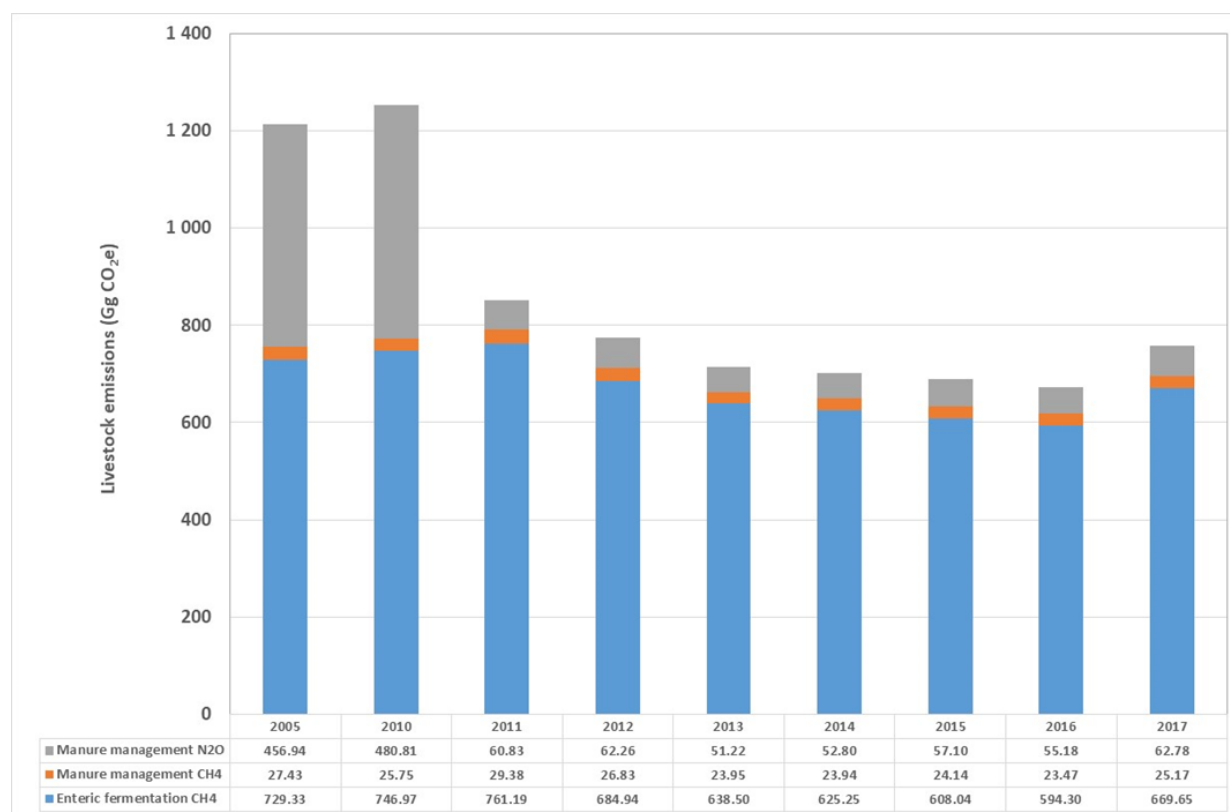


## 6.3 3A: Livestock

### 6.3.1 Emission results and trends

Total livestock emissions are estimated at 758 Gg CO<sub>2</sub>e for 2017. Livestock emissions declined between 2011 and 2016, after which there was an increase in 2017 (**Error! Reference source not found.**). These trends follow the livestock population trend as population number is the main driver in this category. Enteric fermentation is the largest contributor to the emissions in the livestock category, contributing an average of 88.8% between 2011 and 2017. **Error! Reference source not found.** also shows the comparison with the previous inventory for 2005 and 2010. It can be seen that enteric fermentation and CH<sub>4</sub> manure management emissions are very similar between the two sets of data. On the other hand, N<sub>2</sub>O emissions from manure management are much reduced compared to the last inventory. The main reason for this change is the discrepancy in the manure management usage systems. This is a highly uncertain data and shows the importance of collecting data to improve the accuracy and reduce uncertainty in this category.

**Figure 6-5 Trends in livestock emissions for Lesotho between 2005 and 2017**



## 6.4 3A1 Enteric Fermentation

### 6.4.1 Category information

Enteric fermentation emissions are calculated for all livestock, except poultry as IPCC (2006) states that enteric fermentation from poultry is negligible. A lack of data for poultry means no emission factor is provided by IPCC.

### 6.4.2 Methodological issues

Enteric fermentation emissions were calculated using Tier 1 equations 10.19 and 10.20 from the IPCC 2006 Guidelines. The IPCC 2006 software was utilized to estimate the emissions.

#### 6.4.2.1 Population data

Livestock population data for the inventory are shown in **Error! Reference source not found..** Population data for all livestock was obtained from BOS annual livestock statistics reports (BOS, 2013; 2013a; 2014; 2015b; 2016; 2017; 2018).

A total cattle number is supplied in these reports (Table 3.1 in BOS reports), therefore this number had to be split into dairy and other cattle. To determine the number of dairy cattle the fraction of cattle reared for milk purposes (see Table 3.2 in BOS report) was multiplied by the total number of cattle. The total number of other cows was therefore calculated as the total number of cattle minus the dairy cattle. The total number of cows, number of bulls and percentage of cows reared for milk were obtained from BOS annual livestock statistical reports (Table 3.1 and 3.1 in the report).

Swine population is also provided as a total, but this was split into market and breeding swine using the IPCC default assumption of 90% market swine and 10% breeding swine. This division was done as IPCC 2006 Guidelines provides different factors for market and breeding swine.

**Table 6-3 Livestock population data (head/yr) used in the inventory**

Type	2011	2012	2013	2014	2015	2016	2017
Dairy cattle	6 905	5 772	3 836	8 102	4 575	2 470	6 924
Other cattle	683 982	571 400	544 205	532 031	503 769	491 537	454 649
Sheep	1 552 241	1 556 188	1 410 013	1 346 596	1 356 485	1 432 065	2 041 479
Goats	814 018	886 340	838 650	824 968	813 850	700 509	972 701
Horses	77 089	63 656	59 731	55 397	59 704	59 875	64 410
Mules & asses	148 220	122 133	102 124	103 859	113 778	113 988	124 788
Swine	66 548	91 951	41 040	63 416	90 368	83 190	38 689
Poultry	535 793	509 489	366 584	453 083	443 364	292 024	432 976

### 6.4.2.2 Emission factors

IPCC 2006 default emission factors for Africa (Table 10.11 for cattle; Table 10.10 for other livestock) were applied (**Error! Reference source not found.**).

**Table 6-4 Enteric fermentation emission factors for the various livestock**

Livestock category	CH <sub>4</sub> emission factor (kgCH <sub>4</sub> head <sup>-1</sup> yr <sup>-1</sup> )
Dairy cattle	40
Other cattle	31
Sheep	5
Goats	5
Horses	18
Mules & asses	10
Swine	1

### 6.4.3 Data sources

**Error! Reference source not found.** provides the activity data required for the enteric fermentation emission estimates and where the data was obtained from.

**Table 6-5 Table of data sources for enteric fermentation**

Activity data	Data source
Population data	BOS: Lesotho livestock reports for 2010/11 to 2016/17 (BOS, 2013; 2013a; 2014; 2015b; 2016; 2017; 2018)
Fraction of dairy cows	BOS: Lesotho livestock reports for 2010/11 to 2016/17 (BOS, 2013; 2013a; 2014; 2015b; 2016; 2017; 2018)

### 6.4.4 Uncertainty

Country specific uncertainty data was not supplied, however IPCC 2006 Guidelines indicate that livestock population data usually has an uncertainty of  $\pm 20\%$ , while emission factors have a  $\pm 30\%$ -50% uncertainty.

### 6.4.5 Quality Assurance / Quality Control

All the general QA/QC activities (Appendix B) were undertaken, and for enteric fermentation the population data was checked against FAO data. These data sets were found to be consistent.

### 6.4.6 Planned improvements and recommendations

There are no planned improvements for this category.

## 6.5 3A2 Manure Management

### 6.5.1 Category information

Manure management emissions, for both CH<sub>4</sub> and N<sub>2</sub>O are calculated for all livestock, including poultry.

### 6.5.2 Methodological issues

Population data as discussed under enteric fermentation was applied. In addition, chicken numbers from BOS reports (BOS, 2013; 2013a; 2014; 2015b; 2016; 2017; 2018) were included under manure management. Broilers were separated from all other chickens (layers and other chickens grouped together) due to the different weights and emission factors associated with broiler chickens. IPCC 2006 Guideline default TAM weights (Table 10A4 – 10A8) were used. Enteric fermentation emissions were determined using equation 10.19 and 10.20 in the IPCC 2006 Guidelines.

Manure management data is an important component of the N<sub>2</sub>O emission estimates and there is often a lack of data in this area. The manure management data usage applied in this inventory was derived from various sources (see **Error! Reference source not found..**) and are shown in **Error! Reference source not found..** The manure management is assumed to remain constant for all the years (2011 to 2017). Manure management emissions were determined with a Tier 1 approach in the IPCC 2006 software, which makes use of equations 10.22 (CH<sub>4</sub>) and 10.25 (N<sub>2</sub>O) in the IPCC 2006 Guidelines.

**Table 6-6 Fraction of manure managed in each manure management system for all livestock types**

Livestock	PRP	Daily spread	Solid storage	Dry lot	Burned for fuel	Cattle & swine deep bedding	Pit storage below animal confinement	Liquid slurry	Poultry manure without litter	Poultry manure with litter
Dairy cattle	0.83	0.05	0.01	0	0.06	0.05	0	0	0	0
Other cattle	0.95	0.01	0	0.01	0.03	0	0	0	0	0
Sheep	0.8	0	0.05	0.1	0.05	0	0	0	0	0
Goats	0.8	0	0.05	0.1	0.05	0	0	0	0	0
Horses	0.75	0	0	0.25	0	0	0	0	0	0
Mules and asses	0.75	0	0	0.25	0	0	0	0	0	0
Swine	0	0	0.06	0.87	0	0	0.01	0.06	0	0
Poultry	0	0	0.1	0	0	0	0	0	0.45	0.45

### Emission factors

The IPCC 2006 default manure management CH<sub>4</sub> emission factors for developing countries (Table 10.15) were applied. IPCC 2006 default nitrogen extraction rates for Africa (Table 10.19) along with the direct N<sub>2</sub>O emission factors for the manure management systems (EF3, Table 10.21) were used for estimating manure management N<sub>2</sub>O emissions.



### 6.5.3 Data sources

The activity data for the manure management emission estimates, along with their data sources, are provided in **Error! Reference source not found..**

**Table 6-7 Data sources for enteric fermentation and manure management emissions**

Activity data	Data source
Livestock typical animal mass (TAM)	<ul style="list-style-type: none"> <li>■ IPCC 2006 Guidelines (Tables 10A-4 to 10A-9)</li> </ul>
Manure management data	<ul style="list-style-type: none"> <li>■ Lesotho National GHG Inventory for 2010 for sheep, goats, horses, mules &amp; asses, poultry (LMS, 2018);</li> <li>■ IPCC 2006 Guidelines (Tables 10A-4 to 10A-9) for cattle and swine.</li> </ul>
N excretion rates	<ul style="list-style-type: none"> <li>■ IPCC 2006 Guidelines (Table 10.19)</li> </ul>

### 6.5.4 Uncertainty

Uncertainty on livestock population, as mentioned under enteric fermentation, is estimated to be  $\pm 20\%$ , while the uncertainty on the manure management usage is not known but it is very high. It is estimated to be around  $\pm 50\%$ . The uncertainty on the  $\text{CH}_4$  manure management emission factor is  $\pm 30\%$  and for nitrogen excretion rates it is  $\pm 50\%$  (IPCC 2006 Guidelines). The  $\text{N}_2\text{O}$  emission factors for manure management systems (EF3) all have an uncertainty of a factor of 2.

### 6.5.5 Time series consistency

The time series is consistent for all the data for 2011 to 2017, however there are inconsistencies in the manure management data between this inventory and the previous inventory years (2005, 2010) (LMS, 2018). Data was obtained from the previous inventory, but the source of data was not documented. For cattle and swine the manure management data from the previous inventory was replaced by IPCC default values, while the data for other livestock was taken from the previous inventory as there was no other data source for the information.

### 6.5.6 QA/QC

All the general QA/QC activities (Appendix B) were undertaken, and for manure management emissions the population data was checked against FAOStat (FAO, 2019) data. These data sets were found to be consistent. No other source specific checks were undertaken.

### 6.5.7 Planned improvements and recommendations

In order to improve the  $\text{N}_2\text{O}$  emission estimates from manure management it is recommended that data be collected on the various manure management systems used for the various livestock.

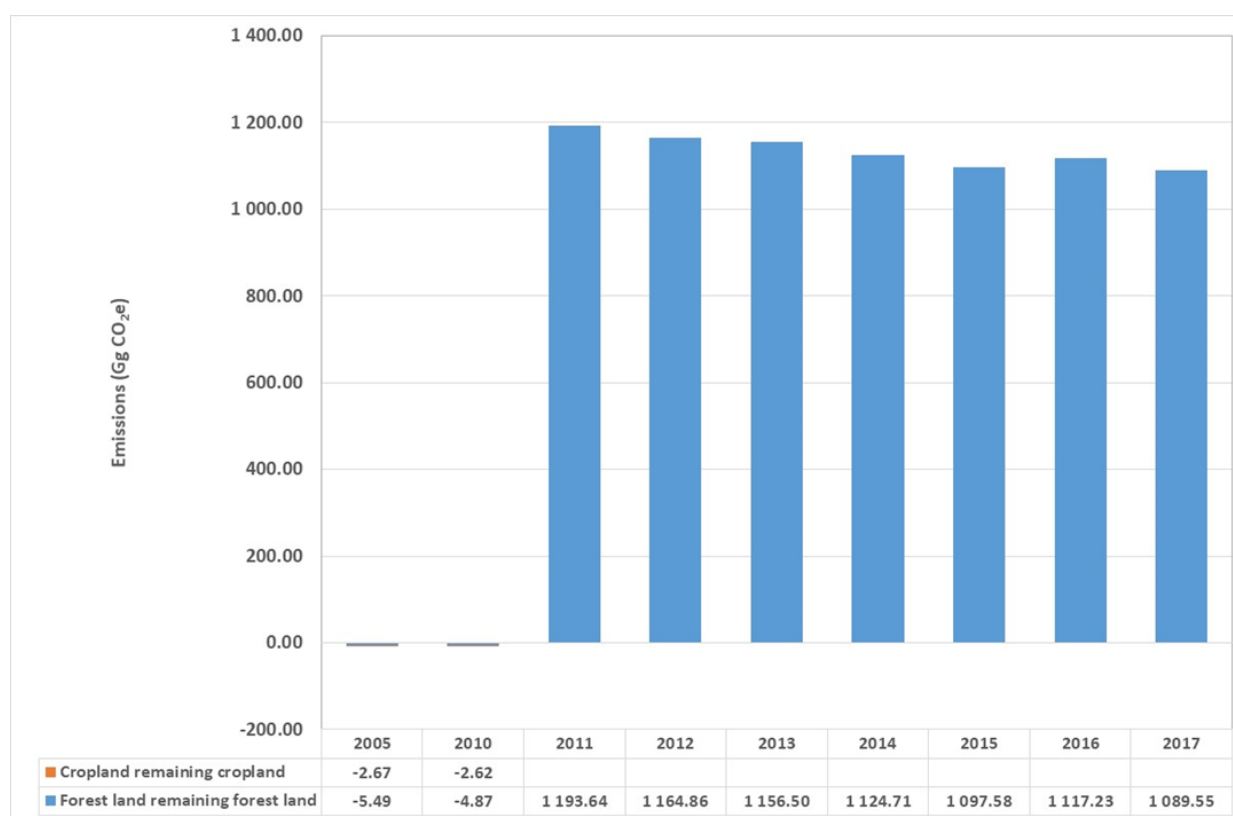
## 6.6 3B: Land

### 6.6.1 Emission results and trends

The land sector for Lesotho was found to be a source of 1 090 Gg CO<sub>2</sub> in 2017 (**Error! Reference source not found.**). This category is, however, not complete as it only included estimates from forest land remaining forest land and also only includes changes in biomass. Emissions from most of the sub-categories have not been estimated due to a lack of data. No land use change area was available therefore all forest land was incorporated into forest land remaining forest land category. The forest land remaining forest land is shown to be a source of CO<sub>2</sub> because of the large amount of wood that is being removed as fuel wood. The drivers in this category therefore are the land areas, and the wood removals. For cropland remaining croplands in this inventory the area was indicated to be annual crops and the Tier 1 assumption for annual crops is that the increase in biomass stocks in a single year is equal to biomass losses from harvest and mortality in the same year, therefore there is no net accumulation of biomass carbon stocks.

There is a large discrepancy between this inventory and the previous inventory because of differences in data sources and methodologies. In the previous inventory only changes due to soil carbon were incorporated for both forest lands and croplands. The data from the previous inventory was not available and not well documented making it difficult to replicate.

**Figure 6-6 Trends in the land emissions (Gg CO<sub>2</sub>e) for Lesotho**



## 6.7 3B1 Forest land

### 6.7.1 Category information

Forest land category includes forest land remaining forest land and land converted to forest land, however no and change data was available. Therefore all the forest land area was included under forest land remaining forest land. Emission estimates were provided for biomass only as land use change, dead organic matter and soil data were not available. As in the FRA (FAO, 2010; 2014), the forest land area was divided into plantations, naturally regenerating forests and other wooded lands. CO<sub>2</sub> emissions from biomass burning were included here as a disturbance loss and not under biomass burning.

Croplands were investigated but since there is no land and because of the equivalence rule applies to annual croplands there is no accumulation of biomass carbon for croplands.

### 6.7.2 Methodological issues

Emissions from changes in biomass in forest land remaining forest land were estimated using the gain-loss method (Equation 2.4 of IPCC 2006 Guidelines). Estimates were made through the assistance of the IPCC 2006 inventory software. The forest areas were obtained from FAOStat (2019a) data. This data was also checked against the Forest Resource Assessment (FRA) for Lesotho (FAO, 2010; 2014). The biomass stocks, root to shoot ratios, and above ground biomass data for forests was obtained from the FRA reports (FAO, 2010; 2014). The factors used to characterize each forest are provided in **Error! Reference source not found..**

**Table 6-8 Carbon factors applied to characterize the forest types**

	Plantation forest	Naturally regenerating forest	Other land wooded	Data source
Age class (yrs)	>20	>20	>20	
Growing stock level (m <sup>3</sup> /ha)	41-80	41-80	<20	FRA (2010; 2015)
Ratio of below ground to above-ground biomass	0.24	0.24	0.24	FRA (2010; 2015)
BCEFr (t/m <sup>3</sup> wood volume)	0.67	0.89	5.55	IPCC 2006 default
Above ground biomass (t dm/ha)	90	50	14.2	FRA (2010, 2015)
Above ground biomass growth (t dm/ha/yr)	10	1.5	1.25	IPCC 2006 default
Wood density (t/m <sup>3</sup> )	0.42	0.42	0.58	FRA (2015)

Disturbance losses due to fire were included, with burnt area being determined as discussed in section 6.9.2 on biomass burning. No harvest data was available, but the FRA indicated all wood removals were for fuel wood use. Fuel wood removal data for 2000 to 2011 was taken from FRA (FAO, 2010; 2014) and extrapolated (linear extrapolation) to 2017. This data was under bark data, so were adjusted to include bark by multiplying by the default factor 1.15. It was not indicated which forest type the wood was removed from, however the FRA report seems to indicate that fuel wood is removed from plantations and naturally

regenerating forests. In order to split the fuel wood removals between these two forest types and area weighting was applied. It was also assumed that all fuel wood was removed as tree parts and not as whole trees.

### 6.7.3 Data sources

Data sources for the land sector are shown in **Error! Reference source not found.** below.

**Table 6-9 Activity data sources for the land sector**

	Activity data	Data source
Carbon gains	Forest land areas	FAOStat (2019b)
	Growth factors	See table 6.7
Carbon losses	Burnt area	FAOStat (2019c)
	Fuel wood removals	FRA for Lesotho (FAO, 2014)

### 6.7.4 Uncertainty

Uncertainty on the area data is not provided, but uncertainty on emission and removal factors are estimated at: basic wood density (40%); annual increment (20%); growing stock (30%) and fuelwood removals (30%).

### 6.7.5 Time series consistency

The time series between 2011 and 2017 is consistent, however this data is not consistent with the previous inventory. In the previous inventory only soil organic carbon changes were included, whereas in this inventory only changes in biomass were included. Data from the previous inventory was not available, therefore could not be included in this inventory.

### 6.7.6 QA/QC

All the regular QA/QC checks were completed (Appendix B), and checks were done between the FRA data, extrapolated fuel wood data and the FAO data and were all found to be consistent.

### 6.7.7 Planned improvements and recommendations

A new forest resource assessment with updated data is currently being developed, but the data could not be incorporated as it is still in the review phase. It is recommended that this data be included in the next inventory. In terms of the SOC data it would be important to try and obtain the data from the previous inventory and include it in the inventory going forward.

Further in the future, and if resources are made available, it would be recommended to develop another land cover map so that changes in land use can be determined. This would allow for the incorporation of data on land conversions.

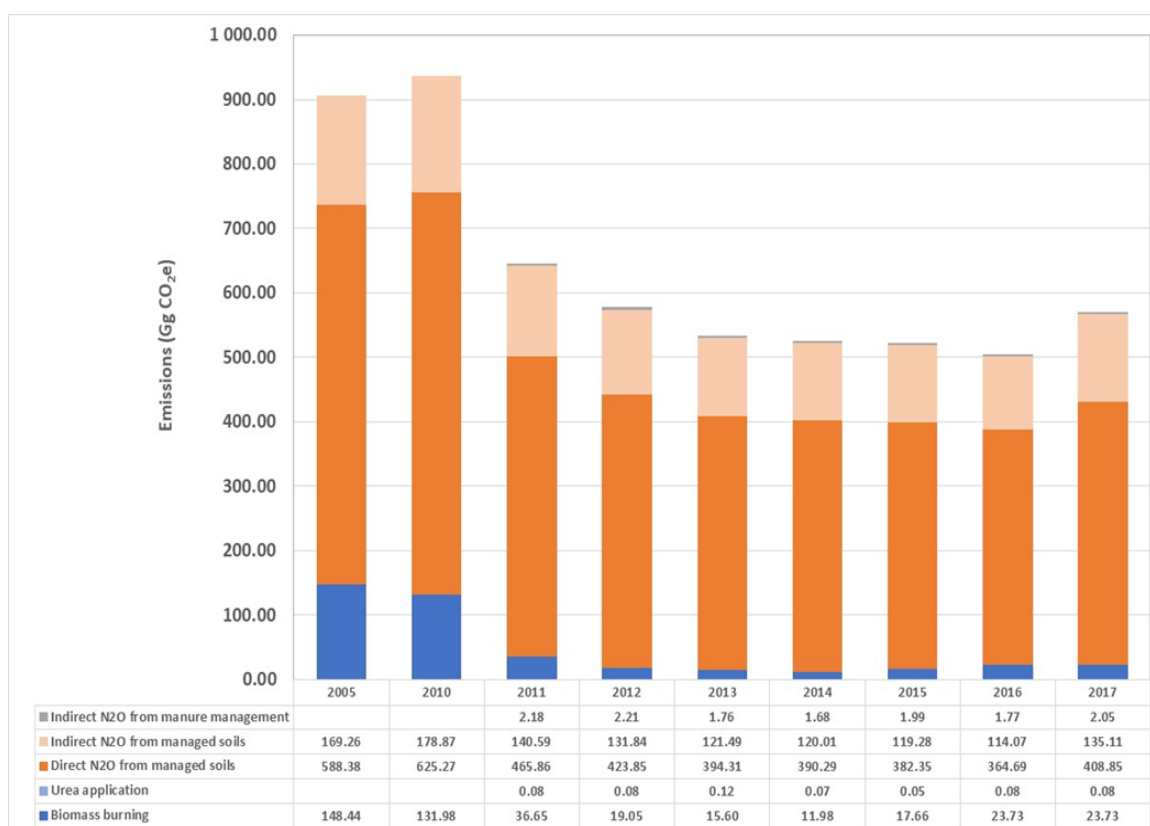
## 6.8 3C: Aggregated non-CO<sub>2</sub> emission sources on land

### 6.8.1 Emission results and trends

Total emissions for aggregated and non-CO<sub>2</sub> emission sources on land were estimated at 570 Gg CO<sub>2</sub>e in 2017. As with livestock emissions, the aggregated and non-CO<sub>2</sub> emissions also decline slowly between 2011 and 2016 after which they increase (**Error! Reference source not found.**). This trend closely follows that of enteric fermentation as well as livestock population numbers. This is because most of the inputs to the managed soil are from livestock (i.e. manure from manure management, or urine and dung inputs from livestock kept in pasture, range and paddock). Therefore, livestock population is again the major driver of these emissions. Direct N<sub>2</sub>O emissions is the largest contributor to emissions in this category, contributing 71.8% in 2017. The inputs due to fertilizers is very small, as is the contribution from indirect N<sub>2</sub>O from managed manure. Direct and indirect N<sub>2</sub>O emissions are in a similar range to the values estimated in the previous inventory, although the direct N<sub>2</sub>O emissions are slightly lower. The difference is due to the difference in the manure management system usage data that was discussed in 6.5.2.

Biomass burning emissions are estimated at 24 Gg CO<sub>2</sub>e in 2017 (**Error! Reference source not found.**), with grasslands contributing 92.3% to these emissions. Biomass burning emissions decline slightly between 2001 and 2014 after which there is a slight increase. Burnt area data is the driver of emission estimates in this category. Biomass burning emissions are very much lower than was estimated in the previous inventory for 2005 and 2010. It is difficult to determine the exact reason for this change as the data sources for the previous inventory were not provided, but it is assumed that there is a difference in the source of the burnt area data.

**Figure 6-7 Emission trends (Gg CO<sub>2</sub>e) for aggregated and non-CO<sub>2</sub> emission sources from land**



## 6.9 3C1 Biomass burning

### 6.9.1 Category information

Emissions of CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, NO<sub>x</sub> and CO from biomass burning are included in this category. The CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions are included in the total GHG emissions for the country, while CO and NO<sub>x</sub> are reported as indirect emissions and are not converted to Gg CO<sub>2</sub>e.

CO<sub>2</sub> emissions for forest burning are included under disturbances in the land category (category 3B1) and are not reported in this biomass burning section. CO<sub>2</sub> emissions for grasslands remaining grasslands are also not included as there is a Tier 1 assumption of equivalence, i.e. all gains and losses in annual grasslands are equal therefore not included.

Biomass burning emissions were only reported for forest lands and grasslands as these are the only land types that are seen to burn. In the previous inventory (LMS, 2018) the IPCC 1996 Guidelines were used and emissions from burning of agricultural residue were determined. This is, however not a specific category in the IPCC 2006 Guidelines. There was also insufficient data on the amount of crop residues that were burnt, therefore crop residue burning was not included in this inventory.

### 6.9.2 Methodological issues

Biomass burning emissions were determined, through the use of the IPCC 2006 inventory software, with equation 2.27 in the IPCC 2006 Guidelines. The activity data for this category is burnt area. Biomass burning emissions are to be determined for each of the 6 IPCC categories. The burnt area for Lesotho is reported as total burnt area and not per land category (AMESD, 2013; 2015). Only reports for the years 2012 to 2015 were available. Furthermore, the burnt area reports did not cover a full year, only the supposed burning season and the period report for each year varied, i.e. April to September for 2012/2013 and June to August for 2014/2015. Due to these inconsistencies in the activity data the FAO data (FAOStat, 2019c) was used instead. The FAO data did not match the country data however the areas were within the range of the AMESD (2013, 2015) reports.

FAO data (FAOStat, 2019c) provided burnt area data for forests for 2012, 2014 and 2015. These numbers were constant; therefore, a constant burnt area was applied to all years for forests. Lesotho forest are divided into forest plantations and naturally regenerating forests. To divide the forest burnt area into these two categories an area weighted average was applied. FAO data also provided burnt areas for other wooded lands and grasslands for the years 2011 to 2016. Burnt area is very variable, so for 2017 a 5-year average burnt area was assumed. This can be corrected in the next inventory when more up-to-date data becomes available. Burnt area data is shown in **Error! Reference source not found.**

The mass of fuel available was determined from values provided in the IPCC 2006 Guidelines (Table 2.4) and is provided in **Error! Reference source not found.** below with an explanation of which values were chosen.

**Table 6-10 Burnt area (ha) data for Lesotho between 2011 and 2017**

Land type	2011	2012	2013	2014	2015	2016	2017
Forest plantation	5.60	6.10	6.59	7.05	7.49	7.92	8.33
Naturally regenerating forest	15.87	15.37	14.88	14.42	13.98	13.55	13.14
Other wooded land	2 640.30	2 103.66	2 447.11	2 253.92	3 627.73	4 507.83	2 988.05
Grassland	101 469.16	51 904.47	41 751.11	31 640.69	46 495.07	62 937.93	62 937.93

### Emission factors

The emission factors and the source are provided in **Error! Reference source not found..**

**Table 6-11 Mass of fuel available (Mb) for burning and emission factors for the various gases**

Land type	Mb*Cf (ton dm ha-1)	CH <sub>4</sub> (g kg-1 dm burnt)	N <sub>2</sub> O (g kg-1 dm burnt)	CO (g kg-1 dm burnt)	NO <sub>x</sub> (g kg-1 dm burnt)
Forest plantation (Eucalyptus forest – wildfire)	53	4.7	0.26	107	3
Naturally regenerating forest (Other temperate forests – wildfire)	19,8	4.7	0.26	107	3
Other wooded land (average of early and late season burn data for savanna woodlands)	2.9	2.3	0.21	65	3.9
Grassland (average of early and late season burn – grassland)	3.1	2.3	0.21	65	3.9

### 6.9.3 Data sources

Burnt area data was obtained from FAOStat (2019c).

### 6.9.4 Uncertainty

Uncertainty on the activity data is not provided. Emission factors have an uncertainty of ±30%.



### **6.9.5 Time series consistency**

Time series was consistent for the period 2011 to 2017. Data indicates that there are inconsistencies between this and the previous inventory years (2005, 2010) (LMS, 2018) inventory. Previous inventory data sources were not provided making it difficult to assess the consistency.

### **6.9.6 QA/QC**

All the general QA/QC activities (Appendix B) were undertaken, and burnt area data was checked against the AMESD 2013 and 2015 reports. These data sets were found to provide data in a similar range. No other source specific checks were undertaken.

### **6.9.7 Planned improvements and recommendations**

It is recommended that the inconsistencies in the country burnt area data be investigated so that actual burnt area data can be incorporated. It is also suggested that the burnt area be overlaid with vegetation type to determine the amount of burnt area in each land type.

## **6.10 3C2: Liming**

### **6.10.1 Category information**

CO<sub>2</sub> emissions from liming are included in this category.

### **6.10.2 Methodological issues**

There was insufficient data on lime consumption to include this category. Data was only available for the year 2013 and it is unclear how reliable this data is. This category was therefore excluded.

### **6.10.3 Planned improvements and recommendations**

It is recommended that the current lime consumption figure be verified and further data is sought for the other years.

## **6.11 3C3 Urea application**

### **6.11.1 Category information**

Adding urea to soils leads to a loss of CO<sub>2</sub> that was fixed in the industrial production process. Emissions from urea application were not estimated in the last inventory, therefore it is a new category for the inventory.

### **6.11.2 Methodological issues**

Urea consumption was determined from the subsidy seeds spreadsheet provided by the Ministry of Food and Agriculture (MAFS, 2017), Department of Crops. The data provided the amount of 50kg pockets that are in stock and the number distributed. For this inventory, it was assumed that the amount that was distributed was all applied to agricultural soils in that year.

Data was provided for 2013/2014/2015. The other years there was no urea data entry. It is not clear if this is because no urea was used or if the data was just missing. In this inventory it was assumed the data was missing and an average value (for the three data points) was applied to the other years.

In 2015 there is only the amount distributed to lowlands and not the total distribution. In the previous 2 years lowland distribution was 0.84 and 0.94 % of total distribution. Therefore, an average fraction of 0.89 was used to estimate the total urea distribution.

Emissions were determined with a Tier 1 methodology using IPCC 2006 inventory software (which applies IPCC equation 11.13).

### *Emission factors*

IPCC 2006 default factor of 0.2 ton of C (ton of urea)<sup>-1</sup> was applied.

### **6.11.3 Data sources**

Urea consumption data was obtained from the subsidy seeds spreadsheet provided by the Ministry of Food and Agriculture, Department of Crops (MAFS, 2017).

### **6.11.4 Uncertainty**

Uncertainty in the urea consumption data is not known, but it is thought to be high since direct data on the amount of urea applied to agricultural soils is not provided. Using the Tier 1 method it is assumed that all C in the urea is lost as CO<sub>2</sub> from the atmosphere. This is a conservative approach, and the default emission factors are considered certain.

### **6.11.5 Time series consistency**

The data was extrapolated for the years where data was missing in order to obtain a consistent time series. There was no data in the previous inventory for this category so no comparisons were made for this data set.

### **6.11.6 QA/QC**

All the general QA/QC checks were completed, but no category specific checks were undertaken.

### **6.11.7 Planned improvements and recommendations**

It is recommended that urea consumption data for the full times series is sought in order to present a consistent time series. Furthermore, it would be useful to determine an uncertainty for the urea consumption data.

## 6.12 3C4 Direct N<sub>2</sub>O from managed soils

### 6.12.1 Category information

This category includes N<sub>2</sub>O emissions from nitrogen inputs into agricultural soils. The nitrogen inputs include synthetic nitrogen fertilizers, animal manure application, other organic nitrogen inputs (such as compost and sewage sludge), crop residues and nitrogen from urine and dung. In this inventory all inputs except other organic inputs were included.

### 6.12.2 Methodological issues

Synthetic fertilizer emissions are calculated from N fertilizer consumption data and an emission factor. The amount of N consumed was obtained from the Seed subsidy spreadsheet provided by Ministry of Agriculture and Food Security (MAFS, 2017). It was assumed that the amount distributed was all applied to agricultural fields in that year. These values were further adjusted for the amount of N in each fertilizer type based on the nutrient ratios in the various pockets. Data was available for the years 2013 – 2017, and a straight line extrapolation was applied to estimate the amount consumed in 2011 and 2012. The amount of fertilizer N was used as input to the IPCC software.

The amount of animal manure N applied is determined by adjusting the amount of manure N available (see equation 10.34 of IPCC 2006 Guidelines) for the amount of manure used for feed, burnt for fuel or used for construction. This was done within the IPCC 2006 inventory software. The urine and dung N inputs are the amount of N deposited on pasture, range and paddock by grazing animals and the amount of manure daily spread applied. In other words, it is all the manure that is managed in PRP and daily spread.

The amount of crop residue N available for application was determined following equation 11.6 of the IPCC 2006 software. Crop area, production and yield data was obtained from Agricultural Situation Report (2017). IPCC default factors for fraction of total area under crop that is renewed annually, ratio of above-ground residues dry matter to harvest yield, N content of above-ground residues, the fraction of above-ground residues removed annually, ratio of below-ground residues to harvest yield, and N content of below-ground residues (IPCC, 2006; Table 11.2) were applied to each crop type. Crop residue inputs were not included in the previous inventory, so is a new sub-category to the inventory.

N<sub>2</sub>O emissions from the mineralization of N associated with loss of soil C in organic soils due to land use change is not estimated due to a lack of data.

All emissions were determined using the Tier 1 approach with the assistance of the IPCC 2006 inventory software.

### *Emission factors*

Emissions were determined using the IPCC 2006 default emission factors (IPCC, 2006; Table 11.1).

### 6.12.3 Data sources

The activity data for direct N<sub>2</sub>O emissions from managed soils are shown in Table 6-12.

**Table 6-12 Activity data sources for direct N<sub>2</sub>O emissions from managed soils**

Sub-category	Activity data	Data source
Synthetic fertilizers	Total N fertilizer consumption	Seed subsidy spreadsheet (MAFS, 2017)
Organic fertilizers (animal waste)	Amount of animal waste N available for application to fields	Data from animal manure emissions section
Crop residues	Crop area, crop production, crop yield	Agricultural Situation Report (MAFS, 2016)

#### **6.12.4 Uncertainty**

Uncertainty ranges for the IPCC 2006 default emission factors are provided in the IPCC 2006 Guidelines in table 11.1 and are around -50% to 100%. Uncertainty ranges for the default excretion rates are estimated at about  $\pm 50\%$ , as is the uncertainty on the default N retention values.

#### **6.12.5 Time series consistency**

Synthetic fertilizer N available was extrapolated for the years 2011 and 2012 in order to present a consistent time-series. There is an inconsistency in the organic fertilizer emissions between this time series (2011 and 2017) and the previous inventory (LMS, 2018). This is because of the difference in the manure management data between the two data sets. The source of the manure management data in the previous inventory was unclear, so where possible IPCC default values were applied instead.

#### **6.12.6 QA/QC**

All the general QA/QC checks were completed (Appendix B), as well as some category specific checks. The crop production and yield data was checked against FAO data and the two data sets were found to be the same. There was no fertilizer data in FAO for Lesotho so no further comparisons could be made.

#### **6.12.7 Planned improvements and recommendations**

As mentioned in the animal manure emissions section, it is very important to obtain country specific data on livestock manure management, as this data sets affects direct and indirect N<sub>2</sub>O emissions as well as manure emissions.

## 6.13 3C5 Indirect N<sub>2</sub>O emissions from managed soils

### 6.13.1 Category information

Indirect N<sub>2</sub>O emissions can occur through two pathways, namely (a) volatilization of N as NH<sub>3</sub> and NO<sub>x</sub> and the depositing of these gases and their products onto soil, and (b) the leaching and runoff from land of N from N additions and mineralization of N associated with loss of soil C in organic soils through land use change. In this inventory the indirect emissions from the latter process are not estimated because of a lack of data.

**Figure 6-8 Photo of agricultural land in Lesotho**



Source: Shutterstock

### 6.13.2 Methodological issues

Indirect N<sub>2</sub>O emissions were determined using the N available for application to soils (from synthetic and organic fertilizers, urine and dung inputs and crop residue inputs) as calculated in the previous section and multiplying it with emission factors (see equation 11.9 of IPCC 2006 Guidelines). This is a Tier 1 methodology and estimates were produced through the assistance of the IPCC 2006 inventory software.

#### *Emission factors*

IPCC 2006 default emission factors (Table 11.3 in the guidelines) were applied.

### 6.13.3 Data sources

All data is taken from other sections of the inventory, therefore activity data is detailed in the relevant sections.

#### **6.13.4 Uncertainty**

Uncertainties on indirect N<sub>2</sub>O emission factors are provided in the IPCC 2006 Guidelines in Table 11.3. Uncertainties on the activity data are discussed in the other relevant sections (section 6.5.4 and section 6.12.4).

#### **6.13.5 Time series consistency**

The time series for the period 2011 to 2017 is consistent, however there are inconsistencies in the activity data for indirect N<sub>2</sub>O from animal waste and urine and dung inputs between this inventory and the previous inventory years of 2005 and 2010 (LMS, 2018) data. This is because of the change in manure management data.

#### **6.13.6 QA/QC**

All the general QA/QC checks were completed (Appendix B), and no category specific checks were undertaken.

#### **6.13.7 Planned improvements and recommendations**

There are no planned improvements for this section.

## 6.14 3C6 Indirect N<sub>2</sub>O emissions from manure management

### 6.14.1 Category information

Indirect N<sub>2</sub>O from manure management result from volatile nitrogen losses that occur primarily in the forms of ammonia and NO<sub>x</sub>. Nitrogen losses begin at the point of excretion and continue through on-site management in storage and treatment systems. Nitrogen is also lost through runoff and leaching into the soils from solid storage of manure.

### 6.14.2 Methodological issues

Indirect N<sub>2</sub>O emissions from manure were calculated using the IPCC 2006 inventory software and follow a Tier 1 approach. It is determined by multiplying the amount of nitrogen excreted from livestock and managed in each manure management system by a fraction of volatilized nitrogen (IPCC 2006, equation 10.26).

#### *Emission factors*

IPCC default emission factors were applied.

### 6.14.3 Data sources

The activity data for this section is described in the manure management emissions section (section 6.5.3).

### 6.14.4 Uncertainty

The uncertainty ranges for default N losses due to volatilization of NH<sub>3</sub> and NO<sub>x</sub> and total losses from manure management systems is given in Table 10.22 and 10.23 of the IPCC 2006 Guidelines. The uncertainty associated with default emission factors for nitrogen volatilization and re-deposition, as well as for leaching and runoff, are given in Table 11.3 of the IPCC 2006 Guidelines. Activity data uncertainties are discussed in the relevant sections above.

### 6.14.5 Time series consistency

The time series between 2011 and 2017 is consistent, however there are inconsistencies between this inventory and the previous inventory. This is due to a change in the manure management system data, as described in 6.5.5.

### 6.14.6 QA/QC

All the general QA/QC checks were completed (**Error! Reference source not found.**), and no category specific checks were undertaken.

### 6.14.7 Planned improvements and recommendations

There are no planned improvements for this category.



## 7. WASTE SECTOR

### 7.1 An overview of the Waste sector

Waste sector emissions can arise from the disposal of solid waste, incineration and open burning of waste, biological treatment of waste as well as wastewater treatment and discharge. Lesotho's waste treatment facilities are few and generally in poor condition. The main and largest landfill site is T'sosane landfill site, which is located in the city of Maseru. There is generally poor or no municipal waste management in the rest of the country, and thus residents and industries mostly resort to burning or illegal waste dumping. Some medical facilities are equipped with waste incineration facilities for treatment of their clinical waste.

Although there is no treatment of general municipal waste in Lesotho, there are a number of recovery centres in the country, which collect and recover scrap metal, cans, plastic, white paper and cardboard. However, there are no statistics on the amount of solid waste generated, recycled and disposed of in the country.

Similarly, wastewater management is very limited in Lesotho, with three proper wastewater treatment facilities in Maseru and only evaporation ponds in the other smaller towns around the country. The majority of the residents in the country use VIP toilets and pit latrines.

#### Sources

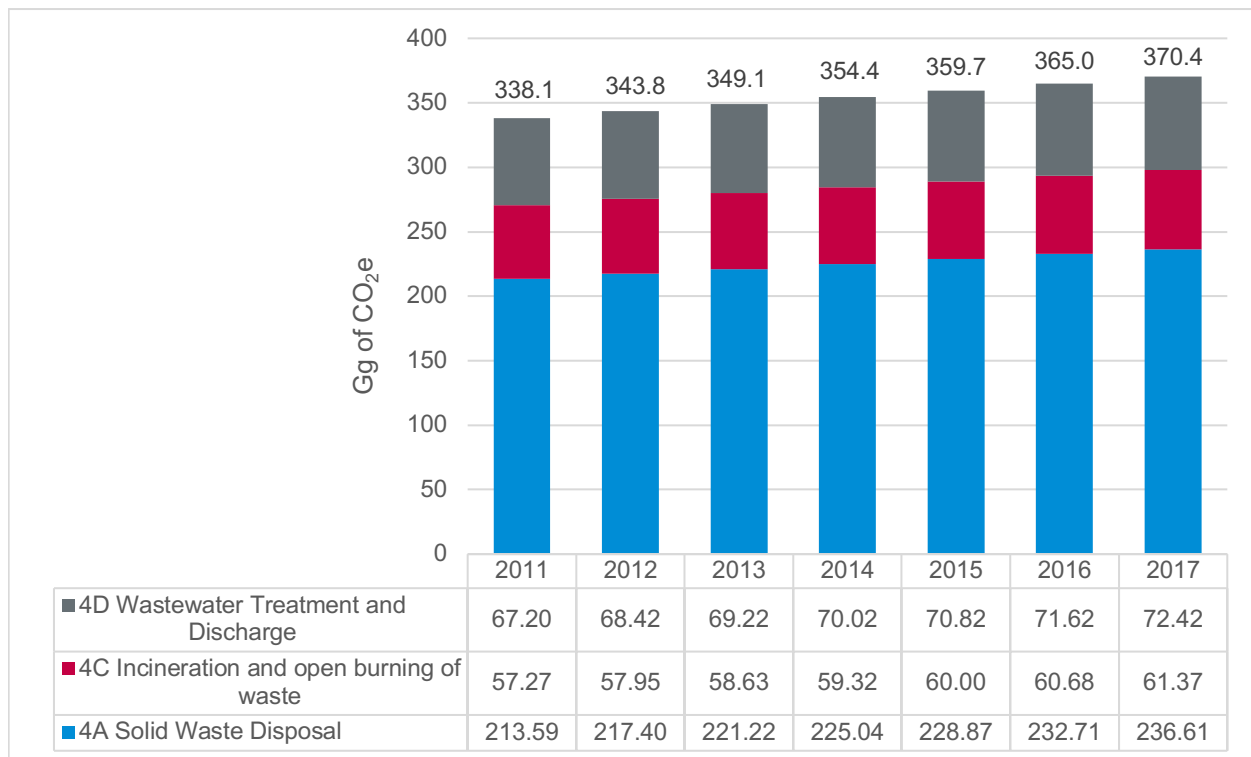
4<sup>th</sup> national GHG inventory for the Waste sector is made up of the following sources:

- 4A Solid Waste Disposal
- 4C Incineration and open burning of waste
- 4D Wastewater treatment and discharge

## 7.2 Results and Trends in the Waste Sector

GHG emissions in the waste sector were estimate at 338.1 Gg CO<sub>2</sub>e and 370.4 Gg CO<sub>2</sub>e in 2011 and 2017 respectively (Figure 7-1 ). This is a 9.56% increase over a period of six years. The largest contributor to waste sector emissions is the disposal of solid waste at 63.2% and 63.9% in 2011 and 2017 respectively. Incineration and open burning of waste is the smallest contributor of GHG emissions in the waste sector with an average contribution of 16.7% over the entire time period.

**Figure 7-1** Graph showing the waste sector emissions from 2011 to 2017, in Gg CO<sub>2</sub>e



## 7.3 4A Solid Waste Disposal

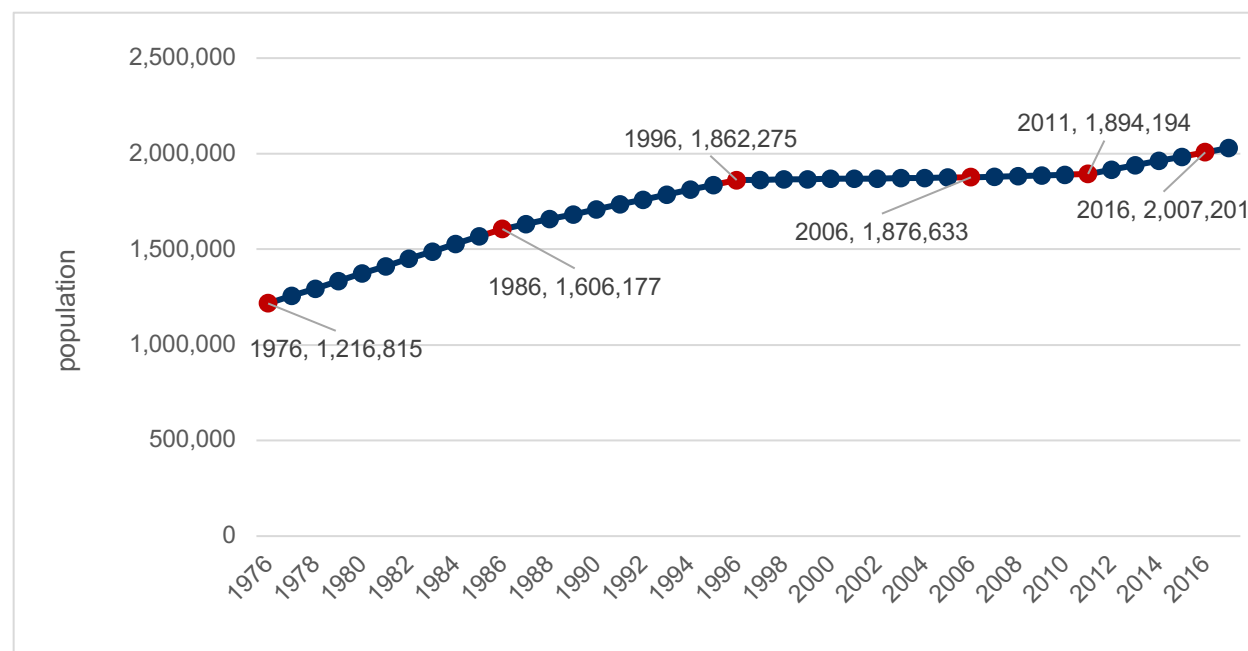
### 7.3.1 Description of sources

The main solid waste disposal site in Maseru is the Tšosane landfill site. The other much smaller dumpsite is at T'soeneng, where industries mostly dump sludge from industrial processes. While there are no statistics on the amount of solid waste generated, recycled and disposed of in Lesotho, two survey studies were commissioned in 2002 and 2006 to investigate urban poverty reduction through municipal solid waste particularly in Maseru and Maputsoe, and to undertake a baseline assessment of waste management with the city of Maseru respectively. The latter study found that 78% of the waste generated in the city does not reach the landfill site, but ends up in dongas, by the road side and/or in open spaces (Thamae, Phomane, Koaleli, & Lombard, 2006).

### 7.3.2 Data sources and Methodological Issues

Tier 1 approach was used to estimate GHG emissions from solid waste disposal in Lesotho. A time series of population growth was generated based on three published censuses and household surveys, namely the 2006 Lesotho Population and Housing Census (Bureau of Statistics, 2006), the 2011 Lesotho Demographic Survey (Bureau of Statistics, 2018) and the 2016 Lesotho Population and Housing Census (Bureau of Statistics, 2018). The 2006 Population and Housing Census also contained a summary of the data from the 1976 and 1986 Population Censuses. The population for the years between these censuses and surveys were estimated by linear interpolation. Figure 7-2 below presents a time-series of the country's population between 1976 and 2017.

**Figure 7-2 Lesotho's population between 1976 and 2017**



To estimate the average waste generation per capita, the results of the two survey studies by Mvuma and Thamae et al were utilized. This involved extrapolation of waste generation in Maseru for the entire country.

According to the surveys, the total waste generated in Maseru was 161 141 tons in 2002 and 244 832 tons in 2006 (Table 7-1).

**Table 7-1 Maseru waste generation for 2002 and 2006**

Waste Source	2002 Waste generation, in tons per year (Mvuma, 2002)	2006 Waste generation, in tons per year (Thamae, Phomane, Koaleli, & Lombard, 2006)
Residential	20 676	32 900
Industries	4 038	17 878
Commercial outlets	112 838	187 701
Schools	4 038	900
Hospitals, clinics & administrative institutions	3 589*	5 453
<b>TOTAL</b>	<b>161 141</b>	<b>244 832</b>

\*Value estimated by authors of this 4<sup>th</sup> GHG inventory

The amount of residential waste generated in the country in 2006 was estimated based on the 2011 ratio of Maseru residents to Lesotho residents, while the waste generated by the other sources was estimated by assuming that Maseru generates a third of the country's waste from those sources.

Once the 2006 national waste generation was determined, the same ratio of waste generated in Maseru in 2006 to waste generated nationally in 2006 was used to determine the amount of waste generated in Lesotho in 2002 from the results of the Mvuma survey study. From these national waste generation figures for 2002 and 2006, waste per capita generation for each of these years was then calculated to be 268.13 and 406.14 kg of waste per capita respectively. An average of these two values (337.13 kg waste per capita) was applied throughout the time series in order to estimate emissions from solid waste disposal (Table 7-2).

**Table 7-2 Determination of average waste per capita**

Year	Estimated National waste generation (tons)	Kg of waste per capita	Average Kg of waste / capita
2002	501 639	268.13	337.13
2006	762 173	406.14	

Solid waste in Lesotho is primarily disposed of in shallow dumpsites or burnt. To determine the ratio of waste dumped to waste burnt by households, the 2011 Lesotho Demographic Survey was used. The survey shows that 0.94% of households in Lesotho burnt their waste in 2011. For waste generated in other sectors of the economy, it was assumed that 60% of waste is burnt. Overall, it was determined that about 49.8% of the waste generated in the country ends up in solid waste disposal sites, while the rest is burnt.

The Maseru City Council (MCC) provided the quantities of sludge dumped at T'soeneng between 2016 and 2018, while the 2006 quantities were obtained from the Assessment report for the development of an integrated waste management system for Maseru City (Thamae et al, 2006). The sludge quantities for the entire period was then determined by linear interpolation of the 2006, 2016, 2017 and 2018 data as shown in Table 7-3 below.

**Table 7-3 Quantity of Sludge dumped at T'soeneng (tons)**

Year	2006	2011	2012	2013	2014	2015	2016	2017
Sludge	2 073.0	2 215.5	2 244.0	2 272.5	2 301.0	2 329.5	8 116.3	6 132.0

Default waste fractions and methane generation factors for shallow solid waste disposal sites were assumed for emission calculations.

### 7.3.3 Solid Waste Emissions and trends

Table 7-4 below shows the methane emissions from the easily biodegradable waste as well as from carbon stored in the paper and wood wastes. In total, methane emissions from solid waste disposal amounted to 213.59 GgCO<sub>2e</sub> in 2011 and then grew by 10.8% to 236.61 Gg CO<sub>2e</sub> in 2017.

**Table 7-4 Methane emissions from Solid Waste Disposal in Lesotho from 2011 to 2017, in Gg CO<sub>2e</sub>**

4 Waste	2011	2012	2013	2014	2015	2016	2017
<b>4A Solid Waste Disposal</b>	<b>213.59</b>	<b>217.40</b>	<b>221.22</b>	<b>225.04</b>	<b>228.87</b>	<b>232.71</b>	<b>236.61</b>
Easily biodegradable CH <sub>4</sub>	120.23	122.30	124.38	126.46	128.55	130.64	132.79
Stored carbon CH <sub>4</sub> – paper	65.62	66.71	67.81	68.90	70.00	71.09	72.19
Stored carbon CH <sub>4</sub> - wood	27.74	28.38	29.03	29.68	30.33	30.98	31.63

### 7.3.4 Uncertainty assessment

The biggest uncertainty for this category lies in the activity data because there are no national statistics of solid waste in the country. According the 2006 IPCC guidelines, the uncertainty associated with the type of data used in this inventory is at least 60%.

Uncertainties associated with various elements of the default emission factors and methodology are as follows:

- Methane correction factor calculated for this inventory was 4.2, which carries an uncertainty of 30%
- Default fraction of CH<sub>4</sub> generated in landfills carries 5% uncertainty
- Uncertainty associated with the estimated half-life is in the range of 14% - 21%.

Overall, the emission estimates in this category carry uncertainties in the range of 60%.

### **7.3.5 Quality assurance/ Quality control**

Quality control was performed by the Waste team as per QC sheet in Appendix B, while data was being collected, when calculations were being performed and while the data was recoded in excel spreadsheets and the final numbers were added into the IPCC software. Specific solid waste QC activities included checking that population data was properly interpolated and recorded, checking the calculations for estimating the average waste generation per capita, checking the interpolation calculations for sludge and checking the calculations for percentage of waste that ends up in solid waste disposal sites.

ERM reviewed all the activity data, calculations and results and made corrections and updates where necessary.

### **7.3.6 Planned improvements and recommendations**

To improve the solid waste disposal emissions inventory the following improvements are recommended:

- Improved estimates of national waste generation: It is recommended that a survey be undertaken at national level to determine the amount and composition of waste generated nationally. This can be complimented by frequent surveys for the city of Maseru.
- Improved estimates of waste going to T'sosane landfill site: It is recommended that weigh bridges be utilized at the landfill site to record the quantities of waste that are disposed of at that landfill site. This can be complimented by visual determination of waste composition in each truck load.

## 7.4 4C Incineration and Open Burning of Waste

### 7.4.1 Description of sources

About 44% of the health care facilities in Lesotho use incinerators to treat their medical and clinical waste, while the rest use open pit burning (Thamae, Phomane, Koaleli, & Lombard, 2006). Section 7.3.2 shows that about 50.2% of all municipal waste is openly burnt in Lesotho.

### 7.4.2 Data Sources and Methodological issues

**Incineration of medical waste** – The quantity of medical waste incinerated in 2012 was obtained from a 2012 Lesotho Healthcare Waste Study Report 2012 from a study undertaken by COWI Consultants (COWI Consulting, 2012). This report estimates the annual clinical waste incinerated in the country at 156,500 Kg/year. This value was applied throughout the entire time series. Default dry matter content, fossil carbon content and total carbon content factors were used for emission calculations.

**Open Burning of waste** – It was calculated based on the estimation that 50.2% of the total waste generated in the country is burnt (See section 7.3.2). Default emission factors were used for emission calculations.

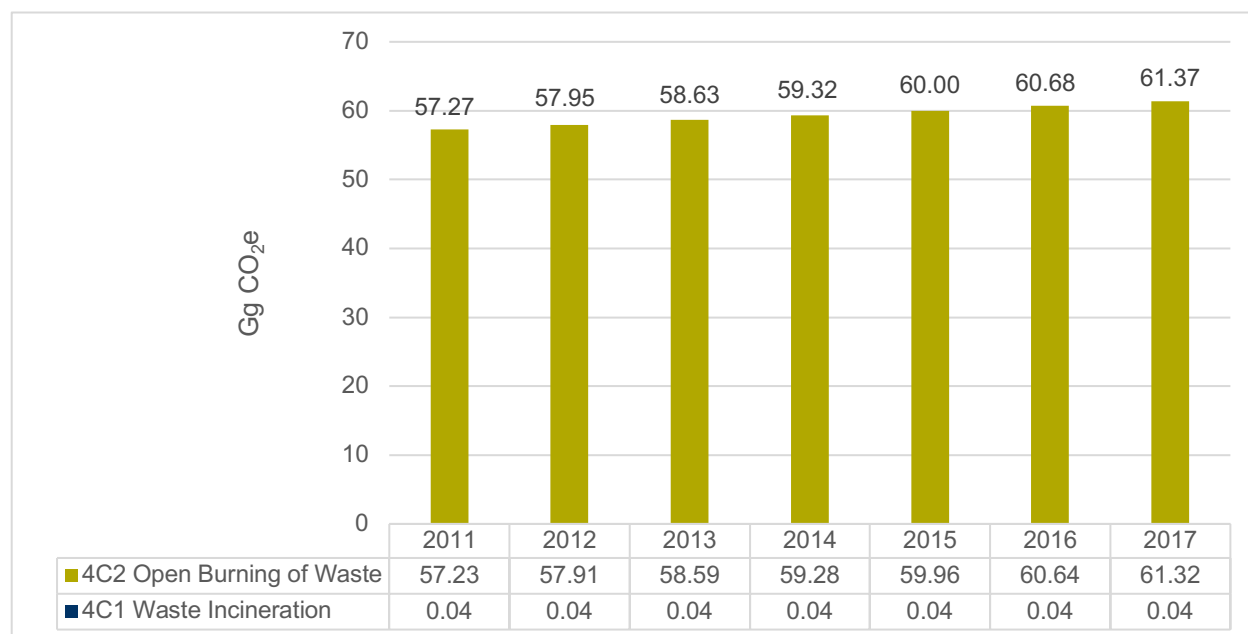
### 7.4.3 Results and Trends

Table 7-5 and Figure 7-3 below present the CO<sub>2</sub>e emission from incineration of clinical waste and open burning of waste for the time series of 2011 – 2017 in Lesotho. The emissions in the category vary from 57.27 Gg CO<sub>2</sub>e in 2011 to 61.37 Gg in 2017. Emissions from open burning of waste account for 99.9% of the emissions yearly.

**Table 7-5 Emissions in Gg CO<sub>2</sub>e from incineration and open burning of waste in Lesotho from 2011 to 2017, disaggregated by gas**

4 Waste	2011	2012	2013	2014	2015	2016	2017
<b>4C Incineration and Open Burning of Waste</b>	<b>57.27</b>	<b>57.95</b>	<b>58.63</b>	<b>59.32</b>	<b>60.00</b>	<b>60.68</b>	<b>61.37</b>
<b>4C1 Waste Incineration</b>	<b>0.041</b>	<b>0.041</b>	<b>0.041</b>	<b>0.041</b>	<b>0.041</b>	<b>0.041</b>	<b>0.041</b>
CO <sub>2</sub>	0.037	0.037	0.037	0.037	0.037	0.037	0.037
CH <sub>4</sub>	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N <sub>2</sub> O	0.003	0.003	0.003	0.003	0.003	0.003	0.003
<b>4C2 Open Burning of Waste</b>	<b>57.23</b>	<b>57.91</b>	<b>58.59</b>	<b>59.28</b>	<b>59.96</b>	<b>60.64</b>	<b>61.32</b>
CO <sub>2</sub>	4.974	5.033	5.093	5.152	5.212	5.271	5.330
CH <sub>4</sub>	43.759	44.281	44.803	45.325	45.847	46.369	46.890
N <sub>2</sub> O	8.497	8.599	8.699	8.801	8.903	9.002	9.105



**Figure 7-3 Incineration and open burning of waste emissions from 2011 to 2017**

#### 7.4.4 Uncertainty assessment

The activity data used for estimating emissions from open burning of waste, which make up 99.9% of the emissions in this category, is the same as that used for estimating emissions from solid waste disposal, hence the uncertainty is also the same at 60%.

#### 7.4.5 Quality assurance/ Quality control

Quality control was performed by the Waste team as per QC sheet in Appendix B while data was being collected, when calculations were being performed and while the data was recoded in excel spreadsheets and the final numbers were added into the IPCC software. ERM then checked the quality of the inventory for incineration and open burning of waste and all the calculators and final numbers, and made updates and adjustments as necessary.

#### 7.4.6 Planned improvements and recommendations

In addition to the recommendations for improving the emissions from solid waste disposal, it is recommended that surveys of the quantity of clinical waste incinerated in medical healthcare facilities be undertaken more frequently.

## 7.5 4D Waste Water Treatment and Discharge

### 7.5.1 Description of sources

Other than the small evaporation ponds located in all the towns across the country, there are three fully-equipped wastewater treatment facilities in Lesotho, all located in Maseru. The Ratjomose wastewater treatment works (WWTW) is the largest wastewater treatment facility Lesotho, serving approximately 41 200 residents (WASCO, 2019). The Plant makes use of both the conventional and waste stabilization pond methods to treat or purify sewage. It is located on the South West of Maseru on the banks of the Mohokare (Caledon). The Agric and Masooe wastewater treatment facilities combined serve a population of 35 722 per year.

**Figure 7-4 View of the Ratjomose wastewater treatment plant from Mpilo hill**



Photo taken by Ewa Matuszewska, ERM, 2019

### 7.5.2 Data Sources and Methodological issues

The default 2006 IPCC method based on population was used to calculate emissions for this category. The categorization of wastewater treatment was based on the 2011 Household survey results as shown in Table 7-6 below. Over 80% of the urban population uses VIP and pit latrine toilets, while 9.3% have no toilet facilities. In the rural areas the two are matched at about 50% each.

**Table 7-6 Household Wastewater treatment in Lesotho (Bureau of Statistics, 2014)**

	Rural %	Urban %
Population	<b>76.3%</b>	<b>23.7%</b>
Toilet facility		
No toilet	49.7%	9.3%
Water sewage system	0.7%	6.1%
Septic tank and conservancy tank	0.5%	1.6%
VIP, pit latrine and public toilet	49.1%	83.0%

A 3-year average protein supply value of 32 g/capita/day from FAO (FAO, 2019) was used to estimate the N<sub>2</sub>O emissions from wastewater treatment and discharge.

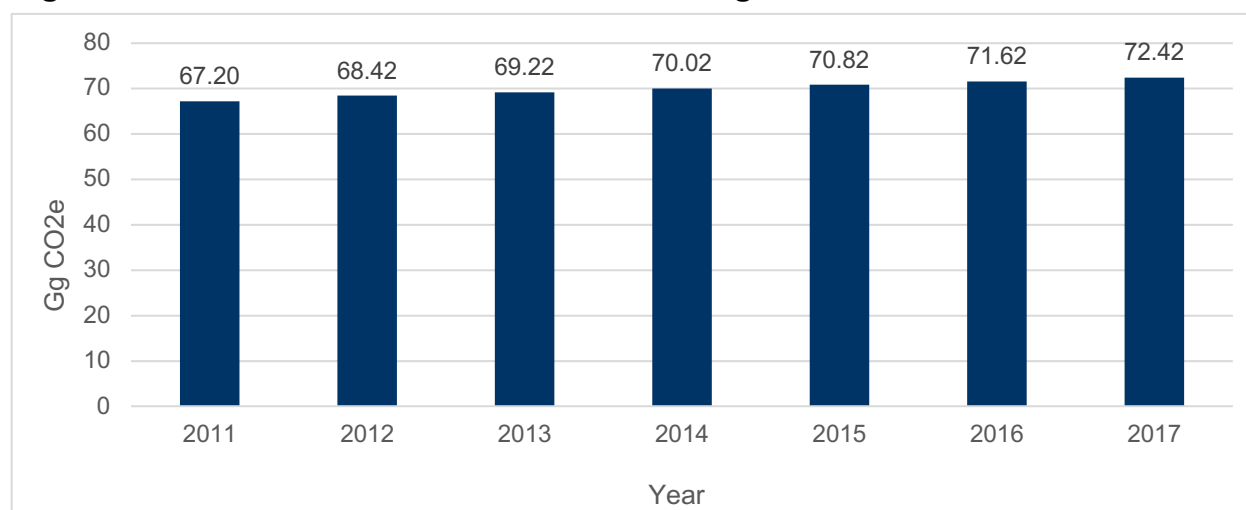
### 7.5.3 Results and Trends

Table 7-7 and Figure 7-5 present the CO<sub>2</sub>e emissions from wastewater treatment and discharge for the time series of 2011 to 2017 in Lesotho. The emissions were 67.20 Gg CO<sub>2</sub>e in 2011, growing to 72.42 Gg CO<sub>2</sub>e by 2017.

**Table 7-7 CO<sub>2</sub>e emissions in Gg for waste water treatment and discharge in Lesotho from 2011 to 2017, disaggregated by gas**

4 Waste							
4D Waste Water Treatment and Discharge	2011	2012	2013	2014	2015	2016	2017
4D1 Domestic Waste Water Treatment and Discharge	67.20	68.42	69.22	70.02	70.82	71.62	72.42
CH <sub>4</sub>	34.71	35.55	35.97	36.38	36.79	37.20	37.61
N <sub>2</sub> O	32.48	32.87	33.26	33.64	34.03	34.42	34.81

**Figure 7-5 Waste water treatment and discharge emissions from 2011 to 2017**



### 7.5.4 Uncertainty assessment

Uncertainty associated with the default emission factor for methane emissions is about 58.3%, while the activity data used carries a combined uncertainty of 64%. Thus the combined uncertainty is about 86.6%.

The activity data used for estimating N<sub>2</sub>O emissions in this category has uncertainty in the range of 6 – 20%. The default emission factors for N<sub>2</sub>O from effluent carry large uncertainties, ranging from 10% to 5000%. Thus the combined uncertainty associated with N<sub>2</sub>O emission is about 5000%.

### **7.5.5 Quality assurance/ Quality control**

Quality control was performed by the Waste team, as per QC sheet in Appendix B, while data was being collected, when calculations were being performed and while the data was recoded in excel spreadsheets and the final numbers were added into the IPCC software. Hence, all the relevant points on the QC sheet were followed for emission calculations for waste water treatment and discharge. The ERM team reviewed and made necessary corrections to all the data, calculations and results.

### **7.5.6 Planned improvements and recommendations**

In order to improve the quality of the wastewater emissions inventory, it is recommended that:

- Accurate monitoring of wastewater flows going to all WWTW and evaporation ponds around the country be done.

## 8. GHG IMPROVEMENT PLAN

The Table below outlines the proposed GHG improvement plan to be implemented by the national inventory agency (LMS), in partnership with relevant institutions and other government departments.

**Table 8-1 Proposed GHG Inventory Improvement Plan for Lesotho**

Sector	Activities	Partners	Output	Timelines
GENERAL	1. Design and implement a National Measurement, Reporting and Verification (MRV) System	All stakeholders that are part of the National Climate Change Committee	Implemented National MRV System	2019 - 2023
	2. Compile a disaggregated, consistent and accurate annual energy balance, based on actual energy consumption data	<ul style="list-style-type: none"> <li>▪ Department of Energy</li> <li>▪ Bureau of Statistics</li> </ul>	Disaggregated annual energy balances	Annually from 2019
ENERGY	3. Strengthen the recording and monitoring procedures for imported fuels at the ports of entry	Lesotho Revenue Authority	Complete and accurate annual statistics of imported fuels	Annually from 2019
	4. Develop or strengthen the Quality Control (QC) and Quality Assurance (QA) procedures for energy data management between Department of Energy, Bureau of Statistics, Lesotho Revenue Authority and LMS.	<ul style="list-style-type: none"> <li>▪ Department of Energy</li> <li>▪ Bureau of Statistics</li> <li>▪ Lesotho Revenue Authority</li> </ul>	New or updated QC and QA procedures developed and documented	By December 2019
IPPU	5. Conduct a national survey to determine the full scale of brick and ceramic production in the country	<ul style="list-style-type: none"> <li>▪ Bureau of Statistics</li> <li>▪ Department of Trade and Industry</li> </ul>	Database of brick and ceramic manufactures and their production quantities	By December 2019 and at least every 5 years thereafter
	6. Sign Memoranda of Understanding (MOUs) with major brick and ceramic manufacturers (making up 90% of national production as informed by the survey), to share		<ul style="list-style-type: none"> <li>▪ Signed MOUs with major brick and ceramic manufacturers</li> </ul>	Before compilation of next GHG inventory

Sector	Activities	Partners	Output	Timelines
	annual production data. Then use the MoUs to collect all previous years' data up to 2017 for recalculations.		<ul style="list-style-type: none"> <li>Activity data for historical years up to 2017</li> </ul>	
	<p>7. Put together a complete and accurate database of all refrigerators, air-conditioning units and HFC gases in the country, dis-aggregated by sub-application, name of HFC gas, quantity of gas, year of introduction and year of import.</p> <p>Existing units and gases can be collected through surveys (including existing household surveys by BOS), while new ones can be tracked through the border gates.</p>	<ul style="list-style-type: none"> <li>Bureau of Statistics</li> <li>Department of Trade and Industry</li> <li>Lesotho Revenue Authority</li> </ul>	Complete and accurate database of refrigerators, air-conditioning units and HFC gases in the country	By December 2019
	<p>8. Identify all key data-providers in the food and beverages industry and sign Memoranda of Understanding with them before the next GHG inventory is compiled. Then use the MoUs to collect all previous years' data up to 2017 for recalculations.</p>		<ul style="list-style-type: none"> <li>Signed MOUs with data providers</li> <li>Food and beverages activity data for historical years up to 2017</li> </ul>	Before compilation of next GHG inventory
AFOLU	<p>9. Include data-collection of manure management systems information for various livestock types in the data-collection process for compiling annual Lesotho Livestock Statistical Reports and Agricultural Production Survey Statistical Reports.</p>	<ul style="list-style-type: none"> <li>Bureau of Statistics</li> <li>Agricultural Research</li> <li>Department of Livestock</li> </ul>	Annual accurate data on manure management systems	From 2020
	<p>10. Include data from the newly undertaken forest resource assessment in the next GHG inventory</p>	Department of Forestry	Up to date forestry activity data	In the next GHG inventory
	<p>11. Develop new land cover maps every five years so that changes in land use and land conversions can be determined.</p>	<ul style="list-style-type: none"> <li>Food and Agricultural Organization</li> <li>Lands Administration Authority</li> </ul>	Up to date land cover maps	2019 and every five years thereafter

Sector	Activities	Partners	Output	Timelines
	12. Develop or strengthen the QC and QA procedures for fertilizer, urea and lime consumption data	Department of Crops	New or updated QC and QA procedures developed and documented	By December 2019
	13. Include data-collection of urea consumption information in the data-collection process for compiling annual Agricultural Production Survey Statistical Reports.	<ul style="list-style-type: none"> <li>▪ Bureau of Statistics</li> <li>▪ Agricultural Research</li> <li>▪ Department of Crops</li> </ul>	Annual accurate data on urea consumption	From 2020
WASTE	14. Undertake a national survey to determine the amount and composition of solid waste generated nationally. This can be complimented by frequent surveys for the city of Maseru.	<ul style="list-style-type: none"> <li>▪ Department of Environment</li> <li>▪ Maseru City Council</li> </ul>	Complete national dataset of solid waste generation and management	Before the next GHG inventory
	15. Installed and utilize weigh bridges at the T'sosane landfill site to record the quantities of waste that are disposed of at that landfill site. This can be complimented by visual determination of waste composition in each truck load	<ul style="list-style-type: none"> <li>▪ Department of Environment</li> <li>▪ Maseru City Council</li> </ul>	Accurate annual data on quantities and categories of waste disposed of at T'sosane landfill site	Weigh bridges to be installed by December 2019
	16. Conduct frequent surveys of the quantity of clinical waste incinerated in medical healthcare facilities. Ideally surveys to be done at least every five years.	<ul style="list-style-type: none"> <li>▪ Ministry of Health</li> <li>▪ Maseru City Council</li> <li>▪ Department of Environment</li> </ul>	Up-to-date activity data on clinical waste incineration	From 2020
	17. Accurately monitor wastewater flows going to all WWTWs and evaporation ponds around the country be done	<ul style="list-style-type: none"> <li>▪ Water and Sewage Company</li> <li>▪ Department of Environment</li> </ul>	Up-to-date activity data on wastewater flows	From January 2020



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## **APPENDIX A      KEY CATEGORY ANALYSES (2010 & 2017)**

### A1 - Level assessment of the 2010 GHG Inventory year

Category Code	Category	Gas	2010 Estimate (Gg CO <sub>2e</sub> )	2010 Absolute Value	Level Assessment (%)	Cumulative Total (%)
1A4b	Residential	CO <sub>2</sub>	1227.51	1227.51	23.91	23.91
3A1	Enteric fermentation	CH <sub>4</sub>	889.25	889.25	17.32	41.22
3C4	Direct emissions from agricultural soils	N <sub>2</sub> O	601.07	601.07	11.71	52.93
1A4a	Commercial / Institutional	CO <sub>2</sub>	506.07	506.07	9.86	62.7
3A2	Animal Waste Management Systems	N <sub>2</sub> O	461.9	461.90	9.00	71.78
1A3b	Road	CO <sub>2</sub>	323.95	323.95	6.31	78.09
1A4b	Residential	CH <sub>4</sub>	261.15	261.15	5.09	83.17
4D	Waste water treatment and discharge	CH <sub>4</sub>	236.00	236.00	4.60	87.77
3C5	Indirect emissions from agricultural soils	N <sub>2</sub> O	171.95	171.95	3.35	91.12
1A4a	Commercial / Institutional	CH <sub>4</sub>	95.58	95.58	1.86	92.98
3C1	Prescribed burning of savannas	CH <sub>4</sub>	76.98	76.98	1.50	94.48
3C1	Prescribed burning of savannas	N <sub>2</sub> O	75.99	75.99	1.48	<b>95.96</b>
1A2	Manufacturing Industries and Construction	CO <sub>2</sub>	72.34	72.34	1.41	<b>97.37</b>
1A4b	Residential	N <sub>2</sub> O	33.44	33.44	0.65	98.02
3A2	Animal Waste Management Systems	CH <sub>4</sub>	30.63	30.63	0.60	98.62
1A4a	Commercial / Institutional	N <sub>2</sub> O	17.25	17.25	0.34	98.95
4D	Waste water treatment and discharge	N <sub>2</sub> O	14.6	14.60	0.28	99.24
4A	Solid waste disposal	CH <sub>4</sub>	12.00	12.00	0.23	99.47
1A4c	Off-road vehicles and machinery	CO <sub>2</sub>	6.72	6.72	0.13	99.60
3B1a	Forest – Forest	CO <sub>2</sub>	-4.87	4.87	0.09	99.69
1A3b	Road	N <sub>2</sub> O	4.74	4.74	0.09	99.79
4C2	Open burning of waste	CH <sub>4</sub>	2.75	2.75	0.05	99.84
3B2a	Cropland - Cropland	CO <sub>2</sub>	-2.62	2.62	0.05	99.89
1A3b	Road	CH <sub>4</sub>	2.3	2.30	0.04	99.94
1A3a	Domestic aviation	CO <sub>2</sub>	1.52	1.52	0.03	99.97
2A	Mineral industry	CO <sub>2</sub>	0.81	0.81	0.02	99.98

4C2	Open burning of waste	CO <sub>2</sub>	0.33	0.33	0.01	99.99
4C2	Open burning of waste	N <sub>2</sub> O	0.3	0.30	0.01	99.99
1A2	Manufacturing Industries and Construction	N <sub>2</sub> O	0.18	0.18	0.00	100.00
1A2	Manufacturing Industries and Construction	CH <sub>4</sub>	0.07	0.07	0.00	100.00
1A4c	Off-road vehicles and machinery	CH <sub>4</sub>	0.02	0.02	0.00	100.00
1A4c	Off-road vehicles and machinery	N <sub>2</sub> O	0.02	0.02	0.00	100.00
1A3a	Domestic aviation	N <sub>2</sub> O	0.01	0.01	0.00	100.00
<b>Totals:</b>			<b>5119.94</b>	<b>5134.92</b>		

### *A2 - Level assessment of the 2017 GHG Inventory year*

Category Code	Category	Gas	2017 Estimate (Gg CO <sub>2e</sub> )	2017 Absolute Value	Level Assessment (%)	Cumulative Total (%)
1A4b	Residential	CO <sub>2</sub>	1553.25	1553.25	27.44%	27.44%
3B1	Forest land	CO <sub>2</sub>	1089.55	1089.55	19.25%	46.69%
3A1	Enteric Fermentation	CH <sub>4</sub>	669.65	669.65	11.83%	58.52%
1A3b	Road Transport	CO <sub>2</sub>	455.77	455.77	8.05%	66.57%
3C4	Direct emissions from managed soils	N <sub>2</sub> O	408.85	408.85	7.22%	73.79%
1A4a	Commercial / Institutional	CO <sub>2</sub>	358.75	358.75	6.34%	80.13%
1A4b	Residential	CH <sub>4</sub>	300.06	300.06	5.30%	85.43%
4A	Solid Waste Disposal	CH <sub>4</sub>	236.61	236.61	4.18%	89.61%
3C6	Indirect emissions from managed soils	N <sub>2</sub> O	135.11	135.11	2.39%	92.00%
3A2	Manure Management	N <sub>2</sub> O	62.78	62.78	1.11%	93.11%
1A2	Manufacturing Industries and Construction	CO <sub>2</sub>	60.82	60.82	1.07%	94.18%
1A4a	Commercial / Institutional	CH <sub>4</sub>	51.89	51.89	0.92%	95.10%
	Residential	N <sub>2</sub> O	47.550	47.550	0.84%	95.94%

Category Code	Category	Gas	2017 Estimate (Gg CO <sub>2e</sub> )	2017 Absolute Value	Level Assessment (%)	Cumulative Total (%)
	Open Burning of Waste	CH <sub>4</sub>	46.890	46.890	0.83%	96.77%
	Wastewater Treatment and discharge	CH <sub>4</sub>	37.612	37.612	0.66%	97.43%
	Wastewater Treatment and discharge	N <sub>2</sub> O	34.806	34.806	0.61%	98.05%
	Manure Management	CH <sub>4</sub>	25.167	25.167	0.44%	98.49%
	Emissions from biomass burning	N <sub>2</sub> O	13.609	13.609	0.24%	98.73%
	Commercial / Institutional	N <sub>2</sub> O	11.817	11.817	0.21%	98.94%
	Emissions from biomass burning	CH <sub>4</sub>	10.124	10.124	0.18%	99.12%
	Agric, Forestry, fishing	CO <sub>2</sub>	9.939	9.939	0.18%	99.30%
	Open Burning of Waste	N <sub>2</sub> O	9.105	9.105	0.16%	99.46%
	Road Transport	N <sub>2</sub> O	6.829	6.829	0.12%	99.58%
	Open Burning of Waste	CO <sub>2</sub>	5.330	5.330	0.09%	99.67%
	Refrigeration and airconditioning	HFC - 125	3.954	3.954	0.07%	99.74%
	Road Transport	CH <sub>4</sub>	3.297	3.297	0.06%	99.80%
	Refrigeration and airconditioning	HFC - 143a	3.237	3.237	0.06%	99.86%
	Refrigeration and airconditioning	HFC-134a	3.171	3.171	0.06%	99.91%
	Indirect N <sub>2</sub> O Emissions from Manure Management	N <sub>2</sub> O	2.055	2.055	0.04%	99.95%
	Ceramics	CO <sub>2</sub>	1.079	1.079	0.02%	99.97%
	Civil Aviation	CO <sub>2</sub>	0.940	0.940	0.02%	99.99%
	Refrigeration and air-conditioning	HFC - 32	0.456	0.456	0.01%	99.99%
	Manufacturing Industries and Construction	N <sub>2</sub> O	0.141	0.141	0.00%	100.00%
	Urea Application	CO <sub>2</sub>	0.080	0.080	0.00%	100.00%
	Manufacturing Industries and Construction	CH <sub>4</sub>	0.049	0.049	0.00%	100.00%

Category Code	Category	Gas	2017 Estimate (Gg CO <sub>2e</sub> )	2017 Absolute Value	Level Assessment (%)	Cumulative Total (%)
	Waste Incineration	CO <sub>2</sub>	0.037	0.037	0.00%	100.00%
	Agric, Forestry, fishing	CH <sub>4</sub>	0.028	0.028	0.00%	100.00%
	Agric, Forestry, fishing	N <sub>2</sub> O	0.025	0.025	0.00%	100.00%
	Civil Aviation	N <sub>2</sub> O	0.008	0.008	0.00%	100.00%
	Waste Incineration	N <sub>2</sub> O	0.003	0.003	0.00%	100.00%
	Waste Incineration	CH <sub>4</sub>	0.000	0.000	0.00%	100.00%
	Civil Aviation	CH <sub>4</sub>	0.000	0.000	0.84%	95.94%
	<b>TOTAL</b>		<b>5 660.43</b>			



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## **APPENDIX B      QUALITY CONTROL SHEET**

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## Appendix B

### QUALITY CONTROL SHEET

Sector: \_\_\_\_\_

Name of Sector compiler: \_\_\_\_\_

Name of Quality controller: \_\_\_\_\_

Date: \_\_\_\_\_

QC Activity	Procedures	Quality Control	
		Done? Tick	Comments
Activity data QC	Check the temporal consistency of the activity data; Check the consistency of the units	<input type="checkbox"/>	
EF data QC	<div><div>■ IPCC default EF:</div><ul style="list-style-type: none"><li>• Check default EF applicability</li><li>• Check temporal consistency</li><li>• Check the consistency of the units</li></ul></div>	<input type="checkbox"/>	
General data QC	1. Check the data calculations <div>a. Reproduce a set of emission/removal calculations</div> <div>b. Calculate Implied Emission Factor</div>	<input type="checkbox"/>	
	2. Check any recalculation data	<input type="checkbox"/>	
	3. Check that emission and removal data are correctly aggregated from lower reporting levels	<input type="checkbox"/>	
	4. Check that the data is compared to previous estimates	<input type="checkbox"/>	
	5. Check for consistency in the trend	<input type="checkbox"/>	
	6. Check for completeness of each subcategory	<input type="checkbox"/>	
Uncertainty QC	<div><div>■ Check that expert judgement is recorded</div><div>■ Check uncertainty calculations</div></div>	<input type="checkbox"/>	

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Database QC	1. Check that the data is in the database	<input type="checkbox"/>	
	2. Check for transcription errors	<input type="checkbox"/>	
	3. Check uncertainty is in the database	<input type="checkbox"/>	
	4. Check for transcription errors in uncertainty data	<input type="checkbox"/>	
	5. Check the correct units have been used in the database	<input type="checkbox"/>	
	6. Check the labels in the database are correct	<input type="checkbox"/>	
	7. Check that data sources / references have been correctly recorded	<input type="checkbox"/>	
	8. Check the correct conversion factors are used	<input type="checkbox"/>	
	9. Check data aggregations are correct		
	10. Check the uncertainty aggregations are correct		
	11. Check that original and supporting documents are attached		

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## **APPENDIX C**

## **NATIONAL GHG INVENTORY TABLES 2011 - 2017**

**Table 9-1 Results of the 2011 National GHG Inventory, in Gg CO<sub>2</sub>e**

Code	Category	2011						
		CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	HFC-32	HFC-125	HFC-134a	HFC-143a
1. ENERGY		2201.79	321.99	59.83				
1A	Fuel Combustion Activities	2201.79	321.99	59.83				
1A2	Manufacturing Industries and Construction	56.55	0.05	0.14				
1A3	Transport	382.30	2.57	5.77				
1A3a	Civil Aviation	0.15	0.00	0.00				
1A3a	Road Transport	382.15	2.57	5.77				
1A4	Other Sectors	1762.94	319.37	53.92				
1A4a	Commercial / Institutional	326.93	46.98	10.76				
1A4b	Residential	1426.22	272.36	43.14				
1A4c	Agric. / Forestry / fish	9.80	0.03	0.02				
2. IPPU*		1.67			0.13	0.92	1.80	0.65
2A	Mineral Industry	1.67						
2A4	Other Process Uses of Carbonates	1.67						
2A4a	Ceramics	1.67						
2F	Product Uses as Substitutes for ODS				0.13	0.92	1.80	0.65
2F1	Refrigeration and Air Conditioning				0.13	0.92	1.80	0.65
2F1a	Refrigeration and Stationery AC				0.13	0.92	1.80	0.65
3. AFOLU		1193.72	806.19	690.49				
3A	Livestock		790.57	60.83				
3A1	Enteric Fermentation		761.19					
3A2	Manure Management		29.38	60.83				
3B	Land	1193.64						
3B1	Forest land	1193.64						
3C	Aggregate sources and non-CO2 emissions sources on land	0.08	15.62	629.66				
3C1	Emissions from biomass burning		15.62	21.03				
3C3	Urea Application	0.08						
3C4	Direct N <sub>2</sub> O emission from managed soils			465.86				
3C5	Indirect N <sub>2</sub> O emission from managed soils			140.59				
3C6	Indirect N <sub>2</sub> O Emissions from Manure Management			2.18				
4. WASTE		5.01	292.07	40.98				
4A	Solid Waste Disposal		213.59					
4C	Incineration and open burning of waste	5.01	43.76	8.50				
4C1	Waste Incineration	0.04	0.00	0.00				
4C2	Open Burning of Waste	4.97	43.76	8.50				
4D	Wastewater Treatment and discharge		34.71	32.48				
TOTAL 2011 INVENTORY (Gg CO <sub>2</sub> e)		3402.20	1420.25	791.30	0.13	0.92	1.80	0.65

\*2H2: Food and Beverage industry emitted 0.0089 Gg of NMVOC in 2011.

**Table 9-2 Results of the 2012 National GHG Inventory, in Gg CO<sub>2</sub>e**

Code	Category	2012						
		CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	HFC-32	HFC-125	HFC-134a	HFC-143a
1. ENERGY		2127.32	326.77	59.60				
1A	Fuel Combustion Activities	2127.32	326.77	59.60				
1A2	Manufacturing Industries and Construction	52.06	0.04	0.13				
1A3	Transport	312.99	2.01	4.75				
1A3a	Civil Aviation	0.43	0.00	0.00				
1A3a	Road Transport	312.56	2.01	4.75				
1A4	Other Sectors	1162.27	324.70	54.72				
1A4a	Commercial / Institutional	332.23	47.80	10.89				
1A4b	Residential	1421.15	276.90	43.80				
1A4b	Agric. / Forestry / fish	8.89	0.03	0.02				
2. IPPU*		1.60			0.17	1.28	2.02	0.95
2A	Mineral Industry	1.60			0.17	1.28	2.02	0.95
2A4	Other Process Uses of Carbonates	1.60						
2A4a	Ceramics	1.60						
2F	Product Uses as Substitutes for ODS				0.17	1.28	2.02	0.95
2F1	Refrigeration and Air Conditioning				0.17	1.28	2.02	0.95
2F1a	Refrigeration and Stationery AC				0.17	1.28	2.02	0.95
3. AFOLU		1164.94	719.90	631.09				
3A	Livestock		711.77	62.26				
3A1	Enteric Fermentation		684.94					
3A2	Manure Management		26.83	62.26				
3B	Land	1164.86						
3B1	Forest land	1164.86						
3C	Aggregate sources and non-CO2 emissions sources on land	0.08	8.13	568.83				
3C1	Emissions from biomass burning		8.13	10.92				
3C3	Urea Application	0.08						
3C4	Direct N <sub>2</sub> O emission from managed soils			423.85				
3C5	Indirect N <sub>2</sub> O emission from managed soils			131.84				
3C6	Indirect N <sub>2</sub> O Emissions from Manure Management			2.21				
4. WASTE		5.07	297.24	41.47				
4A	Solid Waste Disposal		217.40					
4C	Incineration and open burning of waste	5.07	44.28	8.60				
4C1	Waste Incineration	0.04	0.00	0.00				
4C2	Open Burning of Waste	5.03	44.28	8.60				
4D	Wastewater Treatment and discharge		35.55	32.87				
TOTAL 2012 INVENTORY (Gg CO <sub>2</sub> e)		3298.93	1343.90	732.15	0.17	1.28	2.02	0.95

\*2H2: Food and Beverage industry emitted 0.0096 Gg of NMVOC in 2012.

**Table 9-3 Results of the 2013 National GHG Inventory, in Gg CO<sub>2</sub>e**

Code	Category	2013						
		CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	HFC-32	HFC-125	HFC-134a	HFC-143a
1. ENERGY		2152.79	332.18	60.51				
1A	Fuel Combustion Activities	2152.79	332.18	60.51				
1A2	Manufacturing Industries and Construction	53.24	0.04	0.13				
1A3	Transport	312.41	1.98	4.75				
1A3a	Civil Aviation	0.80	0.00	0.01				
1A3a	Road Transport	311.61	1.98	4.74				
1A4	Other Sectors	1787.14	330.15	55.64				
1A4a	Commercial / Institutional	337.53	48.62	11.08				
1A4b	Residential	1440.61	281.51	44.53				
1A4b	Agric. / Forestry / fish	8.99	0.03	0.02				
2. IPPU*		1.07			0.18	1.51	2.03	1.24
2A	Mineral Industry	1.07						
2A4	Other Process Uses of Carbonates	1.07						
2A4a	Ceramics	1.07						
2F	Product Uses as Substitutes for ODS				0.18	1.51	2.03	1.24
2F1	Refrigeration and Air Conditioning				0.18	1.51	2.03	1.24
2F1a	Refrigeration and Stationery AC				0.18	1.51	2.03	1.24
3. AFOLU		1156.62	669.10	577.72				
3A	Livestock		662.44	51.22				
3A1	Enteric Fermentation		638.50					
3A2	Manure Management		23.95	51.22				
3B	Land	1156.50						
3B1	Forest land	1156.60						
3C	Aggregate sources and non-CO2 emissions sources on land	0.12	6.66	526.50				
3C1	Emissions from biomass burning		6.66	8.94				
3C3	Urea Application	0.12						
3C4	Direct N <sub>2</sub> O emission from managed soils			394.31				
3C5	Indirect N <sub>2</sub> O emission from managed soils			121.49				
3C6	Indirect N <sub>2</sub> O Emissions from Manure Management			1.76				
4. WASTE		5.13	301.99	41.96				
4A	Solid Waste Disposal		221.22					
4C	Incineration and open burning of waste	5.13	44.80	8.70				
4C1	Waste Incineration	0.04	0.00	0.00				
4C2	Open Burning of Waste	5.09	44.80	8.70				
4D	Wastewater Treatment and discharge		35.97	33.26				
TOTAL 2013 INVENTORY (Gg CO <sub>2</sub> e)		3315.60	1303.27	680.19	0.18	1.51	2.03	1.21

\*2H2: Food and Beverage industry emitted 0.0085 Gg of NMVOC in 2013.



**Table 9-4 Results of the 2014 National GHG Inventory, in Gg CO<sub>2</sub>e**

Code	Category	2014						
		CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	HFC-32	HFC-125	HFC-134a	HFC-143a
1. ENERGY		2311.66	338.35	63.04				
1A	Fuel Combustion Activities	2311.66	338.35	63.04				
1A2	Manufacturing Industries and Construction	68.08	0.06	0.16				
1A3	Transport	414.08	2.65	6.28				
1A3a	Civil Aviation	0.60	0.00	0.01				
1A3a	Road Transport	413.48	2.65	6.27				
1A4	Other Sectors	1829.51	335.64	56.60				
1A4a	Commercial / Institutional	342.84	49.44	11.26				
1A4b	Residential	1475.11	286.17	45.30				
1A4b	Agric. / Forestry / fish	11.56	0.03	0.03				
2. IPPU*		1.60			0.24	1.73	2.43	1.22
2A	Mineral Industry	1.60						
2A4	Other Process Uses of Carbonates	1.60						
2A4a	Ceramics	1.60						
2F	Product Uses as Substitutes for ODS				0.24	1.73	2.43	1.22
2F1	Refrigeration and Air Conditioning				0.24	1.73	2.43	1.22
2F1a	Refrigeration and Stationery AC				0.24	1.73	2.43	1.22
3. AFOLU		1124.79	654.31	571.65				
3A	Livestock		649.19	52.80				
3A1	Enteric Fermentation		625.25					
3A2	Manure Management		23.94	52.80				
3B	Land	1124.71						
3B1	Forest land	1124.71						
3C	Aggregate sources and non-CO2 emissions sources on land	0.07	5.12	518.84				
3C1	Emissions from biomass burning		5.12	6.86				
3C3	Urea Application	0.07						
3C4	Direct N <sub>2</sub> O emission from managed soils			390.29				
3C5	Indirect N <sub>2</sub> O emission from managed soils			120.01				
3C6	Indirect N <sub>2</sub> O Emissions from Manure Management			1.68				
4. WASTE		5.19	306.75	42.45				
4A	Solid Waste Disposal		225.04					
4C	Incineration and open burning of waste	5.19	45.33	8.80				
4C1	Waste Incineration	0.04	0.00	0.00				
4C2	Open Burning of Waste	5.15	45.33	8.80				
4D	Wastewater Treatment and discharge		36.38	33.64				
TOTAL 2014 INVENTORY (Gg CO <sub>2</sub> e)		3443.25	1299.40	677.13	0.24	1.73	2.43	1.22

**Table 9-5 Results of the 2015 National GHG Inventory, in Gg CO<sub>2</sub>e**

Code	Category	2015						
		CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	HFC-32	HFC-125	HFC-134a	HFC-143a
1. ENERGY		2382.80	344.07	64.57				
1A	Fuel Combustion Activities	2382.75	344.07	64.57				
1A2	Manufacturing Industries and Construction	73.29	0.06	0.17				
1A3	Transport	454.04	2.94	6.88				
1A3a	Civil Aviation	0.67	0.00	0.01				
1A3a	Road Transport	453.37	2.94	6.87				
1A4	Other Sectors	155.43	341.04	57.52				
1A4a	Commercial / Institutional	348.14	50.26	11.45				
1A4b	Residential	1494.89	290.78	46.04				
1A4b	Agric. / Forestry / fish	12.39	0.04	0.03				
2. IPPU*		1.26			0.31	2.55	2.61	2.03
2A	Mineral Industry	1.26						
2A4	Other Process Uses of Carbonates	1.26						
2A4a	Ceramics	1.26						
2F	Product Uses as Substitutes for ODS				0.31	2.55	2.61	2.03
2F1	Refrigeration and Air Conditioning				0.31	2.55	2.61	2.03
2F1a	Refrigeration and Stationery AC				0.31	2.55	2.61	2.03
3. AFOLU		1097.63	639.72	570.84				
3A	Livestock		632.18	57.10				
3A1	Enteric Fermentation		608.04					
3A2	Manure Management		24.14	57.10				
3B	Land	1097.58						
3B1	Forest land	1097.58						
3C	Aggregate sources and non-CO2 emissions sources on land	0.05	7.54	513.74				
3C1	Emissions from biomass burning		7.54	10.12				
3C3	Urea Application	0.05						
3C4	Direct N <sub>2</sub> O emission from managed soils			382.35				
3C5	Indirect N <sub>2</sub> O emission from managed soils			119.28				
3C6	Indirect N <sub>2</sub> O Emissions from Manure Management			1.99				
4. WASTE		5.25	345.54	8.91				
4A	Solid Waste Disposal		228.87					
4C	Incineration and open burning of waste	5.25	45.85	8.91				
4C1	Waste Incineration	0.04	0.00	0.00				
4C2	Open Burning of Waste	5.21	45.85	8.90				
4D	Wastewater Treatment and discharge		36.79	34.03				
TOTAL 2015 INVENTORY (Gg CO <sub>2</sub> e)		3486.89	1295.30	678.35	0.31	2.55	2.61	2.03

\*2H2: Food and Beverage industry emitted 0.009 Gg of NMVOC in 2015.

**Table 9-6 Results of the 2016 National GHG Inventory, in Gg CO<sub>2</sub>e**

Code	Category	2016						
		CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	HFC-32	HFC-125	HFC-134a	HFC-143a
1. ENERGY		2454.11	349.81	66.01				
1A	Fuel Combustion Activities	2454.11	349.81	66.01				
1A2	Manufacturing Industries and Construction	76.58	0.06	0.18				
1A3	Transport	487.38	3.21	7.37				
1A3a	Civil Aviation	0.58	0.00	0.01				
1A3a	Road Transport	486.82	3.21	7.36				
1A4	Other Sectors	1890.13	346.53	58.46				
1A4a	Commercial / Institutional	353.45	51.07	11.63				
1A4b	Residential	1523.80	295.42	46.79				
1A4b	Agric. / Forestry / fish	12.88	0.04	0.03				
2. IPPU*		1.16			0.37	3.21	2.88	2.60
2A	Mineral Industry	1.16						
2A4	Other Process Uses of Carbonates	1.16						
2A4a	Ceramics	1.16						
2F	Product Uses as Substitutes for ODS				0.37	3.21	2.88	2.60
2F1	Refrigeration and Air Conditioning				0.37	3.21	2.88	2.60
2F1a	Refrigeration and Stationery AC				0.37	3.21	2.88	2.60
3. AFOLU		1117.31	627.90	549.32				
3A	Livestock		617.78	55.18				
3A1	Enteric Fermentation		594.30					
3A2	Manure Management		23.47	55.18				
3B	Land	1117.23						
3B1	Forest land	1117.23						
3C	Aggregate sources and non-CO2 emissions sources on land	0.08	10.12	494.13				
3C1	Emissions from biomass burning		10.12	13.61				
3C3	Urea Application	0.08						
3C4	Direct N <sub>2</sub> O emission from managed soils			364.69				
3C5	Indirect N <sub>2</sub> O emission from managed soils			114.07				
3C6	Indirect N <sub>2</sub> O Emissions from Manure Management			1.77				
4. WASTE		5.31	16.28	43.42				
4A	Solid Waste Disposal		232.71					
4C	Incineration and open burning of waste	5.31	43.37	9.01				
4C1	Waste Incineration	0.04	0.00	0.00				
4C2	Open Burning of Waste	5.27	46.37	9.00				
4D	Wastewater Treatment and discharge		37.20	34.42				
TOTAL 2016 INVENTORY (Gg CO <sub>2</sub> e)		3576.73	1293.99	658.75	0.37	3.21	2.88	2.60

\*2H2: Food and Beverage industry emitted 0.0114 Gg of NMVOC in 2016.

**Table 9-7 Results of the 2017 National GHG Inventory, in Gg CO<sub>2</sub>e**

Code	Category	2017						
		CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	HFC-32	HFC-125	HFC-134a	HFC-143a
1. ENERGY		2439.47	355.33	66.37				
1A	Fuel Combustion Activities	2439.47	355.33	66.37				
1A2	Manufacturing Industries and Construction	60.82	0.05	0.14				
1A3	Transport	456.71	3.30	6.84				
1A3a	Civil Aviation	0.58	0.00	0.01				
1A3a	Road Transport	455.77	3.30	6.83				
1A4	Other Sectors	1912.94	351.98	59.39				
1A4a	Commercial / Institutional	358.75	51.89	11.82				
1A4b	Residential	1523.25	300.06	47.55				
1A4b	Agric. / Forestry / fish	9.94	0.03	0.02				
2. IPPU*		1.08			0.46	3.95	3.17	3.24
2A	Mineral Industry	1.08			0.46	3.95	3.17	3.24
2A4	Other Process Uses of Carbonates	1.08						
2A4a	Ceramics	1.08						
2F	Product Uses as Substitutes for ODS				0.46	3.95	3.17	3.24
2F1	Refrigeration and Air Conditioning				0.46	3.95	3.17	3.24
2F1a	Refrigeration and Stationery AC				0.46	3.95	3.17	3.24
3. AFOLU		1089.63	704.94	622.40				
3A	Livestock		694.81	62.78				
3A1	Enteric Fermentation		669.65					
3A2	Manure Management		25.17	62.78				
3B	Land	1089.55						
3B1	Forest land	1089.55						
3C	Aggregate sources and non-CO2 emissions sources on land	0.08	10.12	599.62				
3C1	Emissions from biomass burning		10.12	13.61				
3C3	Urea Application	0.08						
3C4	Direct N <sub>2</sub> O emission from managed soils			408.85				
3C5	Indirect N <sub>2</sub> O emission from managed soils			135.11				
3C6	Indirect N <sub>2</sub> O Emissions from Manure Management			2.05				
4. WASTE		5.37	321.11	43.91				
4A	Solid Waste Disposal		236.61					
4C	Incineration and open burning of waste	5.37	46.89	9.11				
4C1	Waste Incineration	0.04	0.00	0.00				
4C2	Open Burning of Waste	5.33	46.89	9.11				
4D	Wastewater Treatment and discharge		37.61	34.81				
TOTAL 2017 INVENTORY (Gg CO <sub>2</sub> e)		3534.47	1381.38	732.69	0.46	3.95	3.17	3.24

\*2H2: Food and Beverage industry emitted 0.0151 Gg of NMVOC in 2017.

**Table 9-8 Results of the 2011 National GHG Inventory, in Gg**

Code	Category	2011						
		CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	HFC-32	HFC-125	HFC-134a	HFC-143a
1. ENERGY		2201.79	15.21	0.20				
1A	Fuel Combustion Activities	2201.79	15.21	0.17				
1A2	Manufacturing Industries and Construction	56.55	0.00	0.00				
1A3	Transport	382.30	0.12	0.02				
1A3a	Civil Aviation	0.15	0.00	0.00				
1A3a	Road Transport	382.15	0.12	0.02				
1A4	Other Sectors	1762.94	15.21	0.17				
1A4a	Commercial / Institutional	326.93	2.24	0.03				
1A4b	Residential	1426.22	12.97	0.14				
1A4b	Agric. / Forestry / fish	9.80	0.00	0.00				
2. IPPU*		1.67			0.00	0.00	0.00	0.00
2A	Mineral Industry	1.67						
2A4	Other Process Uses of Carbonates	1.67						
2A4a	Ceramics	1.67						
2F	Product Uses as Substitutes for ODS				0.00	0.00	0.00	0.00
2F1	Refrigeration and Air Conditioning				0.00	0.00	0.00	0.00
2F1a	Refrigeration and Stationery AC				0.00	0.00	0.00	0.00
3. AFOLU		1193.72	38.39	2.23				
3A	Livestock		37.65	0.20				
3A1	Enteric Fermentation		36.25					
3A2	Manure Management		1.40	0.20				
3B	Land	1193.64						
3B1	Forest land	1193.64						
3C	Aggregate sources and non-CO2 emissions sources on land	0.08	0.74	2.03				
3C1	Emissions from biomass burning		0.74	0.07				
3C3	Urea Application	0.08						
3C4	Direct N <sub>2</sub> O emission from managed soils			1.50				
3C5	Indirect N <sub>2</sub> O emission from managed soils			0.45				
3C6	Indirect N <sub>2</sub> O Emissions from Manure Management			0.01				
4. WASTE		5.01	12.25	0.03				
4A	Solid Waste Disposal		10.17					
4C	Incineration and open burning of waste	5.01	2.08	0.03				
4C1	Waste Incineration	0.04	0.00	0.00				
4C2	Open Burning of Waste	4.97	2.08	0.03				
4D	Wastewater Treatment and discharge		1.65	0.10				

**Table 9-9 Results of the 2012 National GHG Inventory, in Gg**

Code	Category	2012						
		CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	HFC-32	HFC-125	HFC-134a	HFC-143a
1. ENERGY		2127.32	15.50	0.20				
1A	Fuel Combustion Activities	2127.32	15.46	0.17				
1A2	Manufacturing Industries and Construction	52.06	0.00	0.00				
1A3	Transport	312.99	0.10	0.02				
1A3a	Civil Aviation	0.43	0.00	0.00				
1A3a	Road Transport	312.56	0.10	0.02				
1A4	Other Sectors	1162.27	15.46	0.18				
1A4a	Commercial / Institutional	332.23	2.28	0.04				
1A4b	Residential	1421.15	13.19	0.14				
1A4b	Agric. / Forestry / fish	8.89	0.00	0.00				
2. IPPU*		1.60			0.00	0.00	0.00	0.00
2A	Mineral Industry	1.60						
2A4	Other Process Uses of Carbonates	1.60						
2A4a	Ceramics	1.60						
2F	Product Uses as Substitutes for ODS				0.00	0.00	0.00	0.00
2F1	Refrigeration and Air Conditioning				0.00	0.00	0.00	0.00
2F1a	Refrigeration and Stationery AC				0.00	0.00	0.00	0.00
3. AFOLU		1164.94	34.29	2.03				
3A	Livestock		33.90	0.20				
3A1	Enteric Fermentation		32.62					
3A2	Manure Management		1.28	0.20				
3B	Land	1164.86						
3B1	Forest land	1164.86						
3C	Aggregate sources and non-CO2 emissions sources on land	0.08	0.39	1.83				
3C1	Emissions from biomass burning		0.39	0.04				
3C3	Urea Application	0.08						
3C4	Direct N <sub>2</sub> O emission from managed soils			1.37				
3C5	Indirect N <sub>2</sub> O emission from managed soils			0.43				
3C6	Indirect N <sub>2</sub> O Emissions from Manure Management			0.01				
4. WASTE		5.07	12.46	0.03				
4A	Solid Waste Disposal		10.35					
4C	Incineration and open burning of waste	5.07	2.11	0.03				
4C1	Waste Incineration	0.04	0.00	0.00				
4C2	Open Burning of Waste	5.03	2.11	0.03				
4D	Wastewater Treatment and discharge		1.69	0.11				

**Table 9-10 Results of the 2013 National GHG Inventory, in Gg**

Code	Category	2013						
		CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	HFC-32	HFC-125	HFC-134a	HFC-143a
1. ENERGY		2152.79	2152.79	0.20				
1A	Fuel Combustion Activities	2152.79	15.72	0.20				
1A2	Manufacturing Industries and Construction	53.24	0.00	0.00				
1A3	Transport	312.41	0.09	0.02				
1A3a	Civil Aviation	0.80	0.00	0.00				
1A3a	Road Transport	311.61	0.09	0.02				
1A4	Other Sectors	1787.14	15.72	0.18				
1A4a	Commercial / Institutional	337.53	2.32	0.04				
1A4b	Residential	1440.61	13.41	0.14				
1A4b	Agric. / Forestry / fish	8.99	0.00	0.00				
2. IPPU*		1.07			0.00	0.00	0.00	0.00
2A	Mineral Industry	1.07						
2A4	Other Process Uses of Carbonates	1.07						
2A4a	Ceramics	1.07						
2F	Product Uses as Substitutes for ODS				0.00	0.00	0.00	0.00
2F1	Refrigeration and Air Conditioning				0.00	0.00	0.00	0.00
2F1a	Refrigeration and Stationery AC				0.00	0.00	0.00	0.00
3. AFOLU		1156.62	31.86	1.87				
3A	Livestock		31.54	0.17				
3A1	Enteric Fermentation		30.40					
3A2	Manure Management		1.14	0.17				
3B	Land	1156.50						
3B1	Forest land	1156.60						
3C	Aggregate sources and non-CO2 emissions sources on land	0.12	0.32	1.70				
3C1	Emissions from biomass burning		0.32	0.03				
3C3	Urea Application	0.12						
3C4	Direct N <sub>2</sub> O emission from managed soils			1.27				
3C5	Indirect N <sub>2</sub> O emission from managed soils			0.39				
3C6	Indirect N <sub>2</sub> O Emissions from Manure Management			0.01				
4. WASTE		5.13	12.67	0.03				
4A	Solid Waste Disposal		10.53					
4C	Incineration and open burning of waste	5.13	2.13	0.03				
4C1	Waste Incineration	0.04	0.00	0.00				
4C2	Open Burning of Waste	5.09	2.13	0.03				
4D	Wastewater Treatment and discharge		1.71	0.11				

**Table 9-11 Results of the 2014 National GHG Inventory, in Gg**

Code	Category	2014						
		CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	HFC-32	HFC-125	HFC-134a	HFC-143a
1. ENERGY		2311.66	2311.66	0.20				
1A	Fuel Combustion Activities	2311.66	15.98	0.18				
1A2	Manufacturing Industries and Construction	68.08	0.00	0.00				
1A3	Transport	414.08	0.13	0.02				
1A3a	Civil Aviation	0.60	0.00	0.00				
1A3a	Road Transport	413.48	0.13	0.02				
1A4	Other Sectors	1829.51	15.98	0.19				
1A4a	Commercial / Institutional	342.84	2.35	0.04				
1A4b	Residential	1475.11	13.63	0.15				
1A4b	Agric. / Forestry / fish	11.56	0.00	0.00				
2. IPPU*		1.60			0.00	0.00	0.00	0.00
2A	Mineral Industry	1.60						
2A4	Other Process Uses of Carbonates	1.60						
2A4a	Ceramics	1.60						
2F	Product Uses as Substitutes for ODS				0.00	0.00	0.00	0.00
2F1	Refrigeration and Air Conditioning				0.00	0.00	0.00	0.00
2F1a	Refrigeration and Stationery AC				0.00	0.00	0.00	0.00
3. AFOLU		1124.78	31.15	1.84				
3A	Livestock		30.91	0.17				
3A1	Enteric Fermentation		29.77					
3A2	Manure Management		1.14	0.17				
3B	Land	1124.71						
3B1	Forest land	1124.71						
3C	Aggregate sources and non-CO2 emissions sources on land	0.07	0.24	1.67				
3C1	Emissions from biomass burning		0.24	0.02				
3C3	Urea Application	0.07						
3C4	Direct N <sub>2</sub> O emission from managed soils			1.26				
3C5	Indirect N <sub>2</sub> O emission from managed soils			0.39				
3C6	Indirect N <sub>2</sub> O Emissions from Manure Management			0.01				
4. WASTE		5.19	12.87	0.03				
4A	Solid Waste Disposal		10.72					
4C	Incineration and open burning of waste	5.19	2.16	0.03				
4C1	Waste Incineration	0.04	0.00	0.00				
4C2	Open Burning of Waste	5.15	2.16	0.03				
4D	Wastewater Treatment and discharge		1.73	0.11				



**Table 9-12 Results of the 2015 National GHG Inventory, in Gg**

Code	Category	2015						
		CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	HFC-32	HFC-125	HFC-134a	HFC-143a
1. ENERGY		2382.75	16.24	0.20				
1A	Fuel Combustion Activities	2382.75	16.24	0.19				
1A2	Manufacturing Industries and Construction	73.29	0.00	0.00				
1A3	Transport	454.04	0.14	0.02				
1A3a	Civil Aviation	0.67	0.00	0.00				
1A3a	Road Transport	453.37	0.14	0.02				
1A4	Other Sectors	155.43	16.24	0.19				
1A4a	Commercial / Institutional	348.14	2.39	0.04				
1A4b	Residential	1494.89	13.85	0.15				
1A4b	Agric. / Forestry / fish	12.39	0.00	0.00				
2. IPPU*		1.26			0.00	0.00	0.00	0.00
2A	Mineral Industry	1.26						
2A4	Other Process Uses of Carbonates	1.26						
2A4a	Ceramics	1.26						
2F	Product Uses as Substitutes for ODS				0.00	0.00	0.00	0.00
2F1	Refrigeration and Air Conditioning				0.00	0.00	0.00	0.00
2F1a	Refrigeration and Stationery AC				0.00	0.00	0.00	0.00
3. AFOLU		1097.63	30.46	1.84				
3A	Livestock		30.10	0.18				
3A1	Enteric Fermentation		28.95					
3A2	Manure Management		1.15	0.18				
3B	Land	1097.58						
3B1	Forest land	1097.58						
3C	Aggregate sources and non-CO2 emissions sources on land	0.05	0.36	1.66				
3C1	Emissions from biomass burning		0.36	0.03				
3C3	Urea Application	0.05						
3C4	Direct N <sub>2</sub> O emission from managed soils			1.23				
3C5	Indirect N <sub>2</sub> O emission from managed soils			0.38				
3C6	Indirect N <sub>2</sub> O Emissions from Manure Management			0.01				
4. WASTE		5.25	13.08	0.03				
4A	Solid Waste Disposal		10.90					
4C	Incineration and open burning of waste	5.25	2.18	0.03				
4C1	Waste Incineration	0.04	0.00	0.00				
4C2	Open Burning of Waste	5.21	2.18	0.03				
4D	Wastewater Treatment and discharge		1.75	0.11				

**Table 9-13 Results of the 2016 National GHG Inventory, in Gg**

Code	Category	2016						
		CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	HFC-32	HFC-125	HFC-134a	HFC-143a
1. ENERGY		2454.11	16.50	0.20				
1A	Fuel Combustion Activities	2454.11	16.50	0.20				
1A2	Manufacturing Industries and Construction	76.58	0.00	0.00				
1A3	Transport	487.38	0.15	0.02				
1A3a	Civil Aviation	0.58	0.00	0.00				
1A3a	Road Transport	486.82	0.15	0.02				
1A4	Other Sectors	1890.13	16.50	0.19				
1A4a	Commercial / Institutional	353.45	2.43	0.04				
1A4b	Residential	1523.80	14.07	0.15				
1A4b	Agric. / Forestry / fish	12.88	0.00	0.00				
2. IPPU*		1.16			0.00	0.00	0.00	0.00
2A	Mineral Industry	1.16						
2A4	Other Process Uses of Carbonates	1.16						
2A4a	Ceramics	1.16						
2F	Product Uses as Substitutes for ODS				0.00	0.00	0.00	0.00
2F1	Refrigeration and Air Conditioning				0.00	0.00	0.00	0.00
2F1a	Refrigeration and Stationery AC				0.00	0.00	0.00	0.00
3. AFOLU		1117.31	29.90	1.77				
3A	Livestock		29.42	0.18				
3A1	Enteric Fermentation		28.30					
3A2	Manure Management		1.12	0.18				
3B	Land	1117.23						
3B1	Forest land	1117.23						
3C	Aggregate sources and non-CO2 emissions sources on land	0.08	0.48	1.59				
3C1	Emissions from biomass burning		0.48	0.04				
3C3	Urea Application	0.08						
3C4	Direct N <sub>2</sub> O emission from managed soils			1.18				
3C5	Indirect N <sub>2</sub> O emission from managed soils			0.37				
3C6	Indirect N <sub>2</sub> O Emissions from Manure Management			0.01				
4. WASTE		5.31	13.29	0.03				
4A	Solid Waste Disposal		11.08					
4C	Incineration and open burning of waste	5.31	2.21	0.03				
4C1	Waste Incineration	0.04	0.00	0.00				
4C2	Open Burning of Waste	5.27	2.21	0.03				
4D	Wastewater Treatment and discharge		1.77	0.11				

**Table 9-14 Results of the 2017 National GHG Inventory, in Gg**

Code	Category	2017						
		CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	HFC-32	HFC-125	HFC-134a	HFC-143a
1. ENERGY		2439.47	16.76	0.19				
1A	Fuel Combustion Activities	2439.47	16.76	0.19				
1A2	Manufacturing Industries and Construction	60.82	0.00	0.00				
1A3	Transport	456.71	0.16	0.02				
1A3a	Civil Aviation	0.58	0.00	0.00				
1A3a	Road Transport	455.77	0.16	0.02				
1A4	Other Sectors	1912.94	16.76	0.19				
1A4a	Commercial / Institutional	358.75	2.47	0.04				
1A4b	Residential	1523.25	14.29	0.15				
1A4b	Agric. / Forestry / fish	9.94	0.00	0.00				
2. IPPU*		1.08			0.00	0.00	0.00	0.00
2A	Mineral Industry	1.08						
2A4	Other Process Uses of Carbonates	1.08						
2A4a	Ceramics	1.08						
2F	Product Uses as Substitutes for ODS				0.00	0.00	0.00	0.00
2F1	Refrigeration and Air Conditioning				0.00	0.00	0.00	0.00
2F1a	Refrigeration and Stationery AC				0.00	0.00	0.00	0.00
3. AFOLU		1089.63	33.57	2.01				
3A	Livestock		33.09	0.20				
3A1	Enteric Fermentation		31.89					
3A2	Manure Management		1.20	0.20				
3B	Land	1089.55						
3B1	Forest land	1089.55						
3C	Aggregate sources and non-CO2 emissions sources on land	0.08	0.48	1.81				
3C1	Emissions from biomass burning		0.48	0.04				
3C3	Urea Application	0.08						
3C4	Direct N <sub>2</sub> O emission from managed soils			1.32				
3C5	Indirect N <sub>2</sub> O emission from managed soils			0.44				
3C6	Indirect N <sub>2</sub> O Emissions from Manure Management			0.01				
4. WASTE		5.37	13.50	0.03				
4A	Solid Waste Disposal		11.27					
4C	Incineration and open burning of waste	5.37	2.23	0.03				
4C1	Waste Incineration	0.04	0.00	0.00				
4C2	Open Burning of Waste	5.33	2.23	0.03				
4D	Wastewater Treatment and discharge		1.79	0.11				

**APPENDIX D      REFERENCE APPROACH**

## Appendix D

The below table (Table 9-4) shows reference approach emissions for the energy sector for 2011 and 2017.

**Table 9-4 2011 and 2017 Reference approach emissions, Gg CO<sub>2</sub>**

Fuel	2011			2017		
	Imports (TJ)	Apparent Consumption (TJ)	Emissions (Gg CO <sub>2</sub> )	Imports (TJ)	Apparent Consumption (TJ)	Emissions (Gg CO <sub>2</sub> )
Crude Oil			0			0
Orimulsion			0			0
Natural Gas Liquids			0			0
Motor Gasoline	3 485	3 485	241.511	4 560	4 560	316.008
Aviation Gasoline	2.17	2.17	6.732	13.43	13.43	0.941
Jet Gasoline			0			0
Jet Kerosene			0	0	0	0
Other Kerosene	1 408	1 408	101.188	1 261	1 261	90.624
Shale Oil			0			0
Gas/Diesel Oil	2 939	2 939	217.681	2 981	2 981	220.793
Residual Fuel Oil			0			0
Liquefied Petroleum Gases	128.06	128.06	8.076	341.85	341.85	21.559
Ethane			0			0
Naphtha			0			0
Bitumen			0			0
Lubricants			0			0
Petroleum Coke			0			0
Refinery Feedstocks			0			0
Refinery Gas			0			0
Paraffin Waxes			0			0
White Spirit and SBP			0			0
Other Petroleum Products			0			0
Anthracite			0			0
Coking Coal			0			0
Other Bituminous Coal	17 262.31	17 262.31	1 633.015	18 915.79	18 915.79	1 789.434
Sub-Bituminous Coal			0			0

Fuel	2011			2017		
	Imports (TJ)	Apparent Consumption (TJ)	Emissions (Gg CO <sub>2</sub> )	Imports (TJ)	Apparent Consumption (TJ)	Emissions (Gg CO <sub>2</sub> )
Lignite			0			0
Oil Shale / Tar Sands			0			0
Brown Coal Briquettes			0			0
Patent Fuel			0			0
Coke Oven Coke / Lignite Coke			0			0
Gas Coke			0			0
Coal Tar			0			0
Natural Gas (Dry)			0			0
Municipal Wastes (nonbiomass fraction)			0			0
Industrial Wastes			0			0
Waste Oils			0			0
Peat			0			0
<b>TOTAL</b>			<b>2 208.204</b>			<b>2 439.358</b>



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