# REPUBLIC OF NAMIBIA

# FIFTH NATIONAL GHG INVENTORY REPORT
# NIR5
# 1990 - 2016

## September 2020

## PART 1

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# Foreword

On behalf of the Government of the Republic of Namibia, allow me the honour and privilege to present Namibia's Stand-alone National GHG Inventory Report (NIR) covering the period 1990 to 2016 accompanying the fourth Biennial Update Report (BUR4) in fulfilment of its obligations as a Non-Annex I (NAI) Party to the United Nations Framework Convention on Climate Change (UNFCCC) in accordance with the enhanced reporting requirements adopted at the 16th and 17th Conference of the Parties (COP).

As you are already aware, Namibia ratified the UNFCCC in 1995 and the Paris Agreement (PA) in 2016. As a signatory to the convention, Namibia has prepared and submitted four National Communications and three Biennial Update Reports (BURs), namely: The Initial National Communication (INC) in 2002; the Second National Communication (SNC) in 2011; the first BUR in 2014 (BUR1); the Third National Communication (TNC) in 2015; the second and third BURs in 2016 and 2018 respectively; and the Fourth National Communication in 2020. Furthermore, Namibia prepared and submitted its Nationally Determined Contributions (NDC) in 2015, which is currently under revision. Namibia has started the process of its fifth National Communication (NC5) to be submitted in 2023.

Namibia is one of the countries who has been so far compliant in terms of its reporting obligations. This NIR provides the GHG profile for Namibia starting from the year 1990 to 2016, making a complete time series as recommended during the previous round of International Consultation and Analysis (ICA) process of its previous BURs. It consists of two parts, the first one on the process of inventory preparation, the emissions for tef ul time series and detailed results for the year 2016 while the second one provides all the results for the 27 years at the national and sectoral levels in addition to the Uncertainties. According to the latest inventory, Namibia still remains a carbon sink, however it remains committed to help combat climate change, as demonstrated in its highly ambitious NDC.

At the national level, Namibia has made numerous strides to further engage itself to play its role in fighting climate change as outlined in the NDC. In 2014, the Cabinet of the Republic of Namibia approved the National Climate Change Strategy and Action Plan (NCCSAP). The NCCSAP, which is currently under implementation, aims at facilitating the realisation of the National Climate Change Policy (NCCP), which was passed in 2011. The strategy adopted in the document is cross-sectoral and will be implemented up to the year 2020. It covers the thematic areas mitigation, adaptation and related cross cutting issues. The strategy is currently undergoing its review.

# Acknowledgements

The Ministry of Environment, Forestry and Tourism, on behalf of the Government of the Republic of Namibia, was entrusted with the responsibility for computing the National Inventory of Greenhouse Gases, within the framework of the preparation of the BUR4 to the United Nations Framework Convention on Climate Change (UNFCCC), for the Republic to meet its obligations as a signatory Party to the Convention. This Ministry acknowledges the valuable financial support received from the Global Environment Facility (GEF) through its implementing agency, the UNDP country office.

Namibia is grateful to all international institutions, namely the Intergovernmental Panel on Climate Change (IPCC) Technical Support Unit, the UNFCCC secretariat and the Global Support Programme of the UN Environment and UNDP for providing very useful handbooks and guidelines for use in the preparation of the final document towards meeting the TCCCA standard. Namibia also wishes to extend its appreciation for the contribution of the representatives of the institutions and private sector organizations, which collaborated in this work, as well as CLIMAGRIC LTD, that offered consultancy services for capacity building of the inventory team, the computation of the Greenhouse gas (GHG) Inventory and the preparation of this National Inventory Report (NIR).

The contribution of the following persons is acknowledged:

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# Abbreviations and acronyms

| Abbreviation / acronym | Definition |
|---|---|
| AD | Activity Data |
| AFOLU | Agriculture, Forestry and Other Land Use |
| bm | Biomass |
| BUR | Biennial Update Report |
| CCU | Climate Change Unit |
| $CH_4$ | Methane |
| CO | Carbon monoxide |
| $CO_2$ | Carbon dioxide |
| $CO_2$-eq | Carbon dioxide equivalent |
| COP | Conference of Parties |
| CS | Country-specific |
| DBH/dbh | Diameter at breast height |
| DE | Digestible Energy |
| DEA | Department of Environmental Affairs |
| dm | Dry Matter |
| ECB | Electricity Control Board |
| EF | Emission Factor |
| EMEP/EEA | European Monitoring and Evaluation Program/European Environment Agency |
| FAO | Food and Agriculture Organisation (of the United Nations) |
| FL | Forest Land |
| FOLU | Forestry and Other Land Use |
| FRA | Global Forest Resources Assessment 2010 |
| GDP | Gross Domestic Product |
| GEF | Global Environment Facility |
| Gg | Gigagram (1000 t) |
| GHG | Greenhouse gas |
| GIZ | Deutsche Gesellschaft für Internationale Zusammenarbeit (German Agency for International Cooperation) |
| GL | Guidelines |
| GWP | Global Warming Potential |
| HAC | High Activity Clay |
| HFC | Hydrofluorocarbon |
| HWP | Harvestable Wood Products |
| HS | Harmonised System |
| IE | Included Elsewhere |
| IEA | International Energy Agency |
| INC | Initial National Communication |
| INDC | Intended Nationally Determined Contribution |

| Abbreviation / acronym | Definition |
|---|---|
| IPCC | Intergovernmental Panel on Climate Change |
| IPPU | Industrial Processes and Product Use |
| KCA | Key Category Analysis |
| LAC | Low Activity Clay |
| LPG | Liquefied Petroleum Gas |
| m | metre |
| M | million |
| MAWF | Ministry of Agriculture, Water Affairs and Forestry |
| MeatCo | Meat Company of Namibia |
| MCF | Methane Correction Factor |
| MET | Ministry of Environment and Tourism |
| MMS | Manure Management System |
| MRV | Measure, Report and Verify |
| N | Nitrogen |
| $N_2O$ | Nitrous oxide |
| NA | Not Applicable |
| NC | National Communication |
| NE | Not Estimated |
| NFI | National Forest Inventory |
| NGO | Non-Governmental Organization |
| NIIP | National Inventory Improvement Plan |
| NIR | National Inventory Report |
| NMVOC | Non-Methane Volatile Organic Compound |
| NNFU | Namibian National Farmers Union |
| NO | Not Occurring |
| $NO_X$ | Oxides of nitrogen |
| NPHC | Namibia Population and Housing Census |
| NSA | Namibia Statistics Agency |
| ODS | Ozone Depleting Substances |
| OL | Other Land |
| OWL | Other Wooded Land |
| PFC | Perfluorocarbon |
| PRP | Pasture range and Padlock |
| QA | Quality assurance |
| QC | Quality Control |
| RA | Reference Approach |
| RAC | Refrigeration and Air Conditioning |
| RCMRD | Regional Centre for Mapping Resource for Development |
| SA | Sectoral Approach |
| SAN | Sandy Mineral |

| Abbreviation / acronym | Definition |
|---|---|
| SAPP | South African Power Pool |
| $SF_6$ | Sulphur hexafluoride |
| SME | Small and Medium Enterprises |
| SNC | Second National Communication |
| $SO_2$ | Sulphur dioxide |
| t | Tonnes |
| TACCC | Transparency, Accuracy, Consistency, Completeness, and Comparability |
| TJ | Tera Joule |
| UN | United Nations |
| UNDP | United Nations Development Programme |
| UNE | United Nations Environment |
| UNFCCC | United Nations Framework Convention on Climate Change |
| WET | Wetland |
| X | Emission Estimated |
| yr / yrs | Year / Years |

# Executive Summary

## ES 1. Introduction

Namibia has been compliant with the Convention with regards to the submission of national inventories of greenhouse gases (GHGs) with seven inventories as components of its four national communications and three Biennial Update Reports. More exhaustive information on the latest inventory can be obtained by perusing the full NIR5 of the country that has also been submitted to the secretariat of the United Nations Framework Convention on Climate Change (UNFCCC) as accompanying document of the Fourth Biennial Update Report. These inventories have been compiled and submitted in line with Article 4.1 (a) of the Convention which stipulates that *each party has to develop, periodically update, publish and make available to the Conference of the Parties (COPs), in accordance with Article 12, national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol*. These inventories have been produced according to the capabilities of the country using recommended methodologies of the Intergovernmental Panel on Climate Change (IPCC) agreed upon by the Conference of the Parties. This exercise of inventory preparation is the eighth one for the country. This NIR5 supersedes all previous inventories and provides for the latest and best emission estimates the country have compiled with available data and information.

## ES 2. Coverage (period and scope)

Namibia compiled and published GHG inventories for the years 1994, 2000 and 2010 for the requirement of national communications. IPCC methodologies have evolved to capture the latest scientific advances and as from the fourth inventory, special efforts have been invested to compile the inventory for a consistent time series and in using the latest IPCC Inventory Software and Guidelines. This NIR5 covers the full recommended time series 1990 to 2016, the latter year being at least 4 years preceding the date of submission of the Biennial Update Report to be in line with Decision 2 CP/17 and recalculated inventories published previously in national communications for the years 1994, 2000 and 2010.

The inventory covered the full territory of the country and the results are presented at the national level. It addressed all the IPCC sectors and categories subject to Activity Data (AD) availability. The latest IPCC 2006 Guidelines, revised version of April 2018 and the IPCC Inventory Software, version 2.691 (released on 23 January 2020) have been used to estimate emissions for the four IPCC sectors Energy, Industrial Processes and Product Use (IPPU), Agriculture, Forestry, and Other Land Use (AFOLU) and Waste.

## ES 3. Institutional arrangements and GHG inventory system

Namibia consolidated the in-house production of its GHG inventory except for the support from a company's services for computation of emissions and report writing and an independent international consultant for performing the Quality Assurance (QA). Capacity building of national experts continued, the objective being to meet the enhanced transparency requirement of the Paris Agreement. Lack of financial resources to maintain permanent staff prevented a full institutionalization of the process. Another impeding factor is the numerous changes in the working groups following staff movements, promotions and resignations. The Climate Change Unit (CCU) of the Ministry of Environment and Tourism, National Focal Point of the Convention, monitors and coordinates the production of reports to the Convention, including the GHG inventories. The same framework adopted for the compilation of the inventory of the NC4 was followed. Collaboration with data providers, institutions and organizations to support derivation of national emission factors (EFs) and enable moving to Tier 2 were consolidated.

The exercise of mapping of national institutions and organizations was renewed to identify any stakeholder that could contribute in one way or the other for the inventory compilation but not yet included in the institutional arrangements. The existing collaboration streams were maintained as they are working satisfactorily. however, there is a need to develop and implement official formal agreements with some data providers to make the process more sustainable. An international consultant was appointed to further capacity building, follow, and guide the team until the production of the final output, which is the NIR5 and its summarization into the chapter for the BUR4. Capacity building of all inventory team members continued on the different steps of the inventory cycle as well as on data management, running the IPCC inventory software, analysis of the outputs and reporting to the Convention. All members were once more engaged to ensure consistency of the inventory as the time series is being extended by another 2 years to include 1990 and 2016.

## ES 4. Methods

### Guidelines and software

The present national GHG inventory has been prepared in accordance with the latest *2006 IPCC Guidelines for National Greenhouse Gas Inventories* and using the IPCC Inventory Software version 2.691 for the compilations. As the IPCC 2006 Guidelines do not extensively cover all GHGs for all categories, it has been supplemented with the European Monitoring and Evaluation Program/European Environment Agency (EMEP/EEA) air pollutant emission inventory guidebook of 2016 for compiling estimates for nitrogen oxides ($NO_x$), carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs) and sulphur dioxide ($SO_2$).

As the IPCC Inventory Software is being further developed to address compilations at the Tier 2 level, derivation of national EFs and stock factors for improving estimates to be made at this level for the Livestock and Land sectors have been done through programming in Excel. Thus, the inventory has been compiled using a mix of Tiers 1 and 2. This is good practice and resulted in improved accuracy of the emission estimates and reduced level of Uncertainty accordingly.

### Gases

The gases covered in this inventory are the direct gases carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$) and hydro-fluorocarbons (HFCs) as well as the indirect gases nitrogen oxides ($NO_x$), carbon monoxide (CO), non-methane organic volatile compounds (NMVOCs) and sulphur dioxide ($SO_2$). Perfluorocarbons (PFCs) and Sulphur hexafluoride ($SF_6$) have not been estimated since AD were not available. However, work started in this area and it is hoped that the next inventory will include these gases also.

### GWPs

Global Warming Potentials (GWP) as recommended by the IPCC have been used to convert GHGs other than $CO_2$ to the latter equivalent. Based on decision 17/CP.8, the values adopted were from the IPCC Second Assessment Report for all direct GHGs.

| Gas | Symbol | Global Warming Potential |
|---|---|---|
| Carbon Dioxide | ($CO_2$) | 1 |
| Methane | ($CH_4$) | 21 |
| Nitrous Oxide | ($N_2O$) | 310 |
| HFC - 32 | (CH2F2) | 650 |
| HFC - 125 | (CH2CF3) | 2,800 |
| HFC - 134a | (CF2FCF3) | 1,300 |
| HFC - 143a | (CF3CH3) | 3,800 |

## ES 5. Activity data

Country-specific AD are readily available as a fairly good statistical system exists since 2003 whereby data pertaining to most of the socio-economic sectors are collected, verified and processed to produce official national statistics reports. Additional and/or missing data, and those required to meet the level of disaggregation for higher than the Tier 1 level, were sourced directly from both public and private sector operators by the working groups and coordinator. Data gaps were filled through personal contacts with the stakeholders by the national experts and/or from results of surveys, scientific studies and by statistical modelling. All the data collected during the inventory process have been stored in the software database and other information documented in worksheets and in the NIRs.

In some cases, due to the restricted timeframe and lack of a declared National framework for data collection and archiving to meet the requirements for preparing GHG inventories, derived data and estimates were used to fill in the gaps. These were considered reliable and sound since they were based on scientific findings and other observations. Estimates used included fuel use for navigation, domestic aviation, food consumption and land areas by IPCC class. Most AD for the period 1990 to 2002 were generated based on related socio-economic factors or through extrapolations from the available time series AD.

## ES 6. Emission factors

Country EFs were derived for the Tier 2 estimation of GHGs for some animal classes for enteric fermentation. Similarly, the same exercise was performed for the Land sector where stock factors have been derived to suit national circumstances. This is Good Practice towards enhancing the quality of the inventory and especially as these activity areas were major emitters based on previous inventory results. Additionally, default IPCC EFs for the remaining source categories were screened for their appropriateness before adoption, based on the situations under which they were developed and the extent to which these were representative of the national circumstances.

## ES 7. Recalculations

Recalculations have been performed during the computation of the present inventory whenever new improved datasets were obtained. Only recalculated emissions for the base years 1994, 2000 and 2010 are provided in this inventory while for the remaining years of the time series, the recalculations can be captured in the sectoral presentations. Original estimates of 1994, 2000 and 2010 were made according to IPCC 1996 Revised GL, Tier 1, lower coverage of activity areas compared to the present inventory and default EFs while recalculated values have been compiled in line with the 2006 IPCC GL, a mix of Tiers 1 and 2, the latter for some key categories, improved datasets and a more exhaustive coverage.

## ES 8. Inventory estimates

### Aggregated emissions

Namibia remained a net GHG sink over the period 1990 to 2016 as the Land category removals exceeded emissions from the other categories. The net removal of $CO_2$ increased by 50% over these 27 years from 70,329 Gg in 1990 to 105,428 Gg in 2016. During the same period, the country recorded an increase of 8% in emissions, from 19,692 Gg $CO_2$-eq to 21,260 Gg $CO_2$-eq. The trend for the period 1990 to 2016 indicates that the total removals from the Land category increased from 90,021 Gg $CO_2$-eq in 1990 to 126,688 Gg $CO_2$-eq in 2016 (Figure ES1).

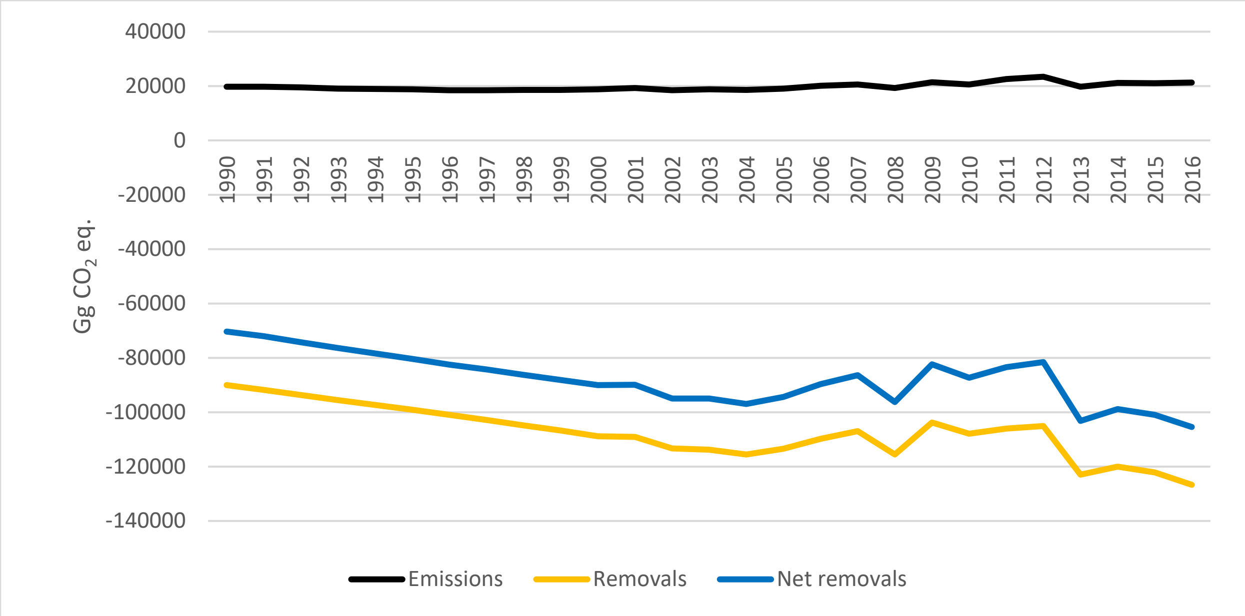


**Figure ES1 - National emissions, removals and net removals (Gg $CO_2$-eq) (1990 – 2016)**

Per capita emissions of GHG decreased gradually from 13.4 tonnes $CO_2$-eq in 1990 to reach 9.1 tonnes in 2016 (Figure ES2). The GDP emission index decreased almost steadily from 100 in the year 1990 to 35 in 2016 (Figure ES3).

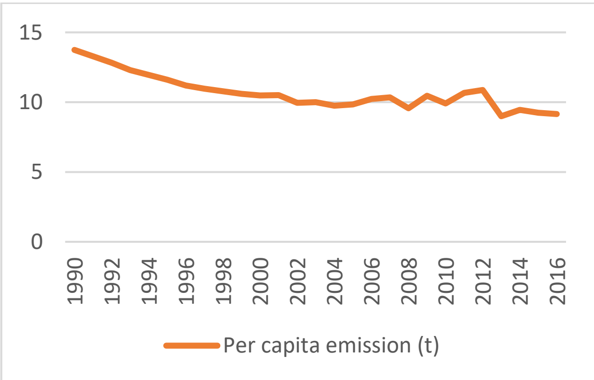


**Figure ES2 - Per capita GHG emissions (1990 - 2016)**

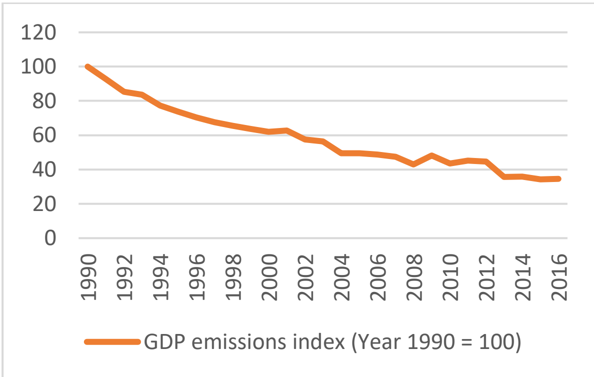


**Figure ES3 - GDP emissions index (1990 - 2016)**

National and sectoral emissions are presented in Table ES1. The AFOLU sector remained the leading emitter throughout this period followed by Energy, for all years under review. Following the setting up of new industries, the IPPU sector took over as the third emitter in lieu of the Waste sector as from the year 2005. Emissions from the AFOLU sector regressed by 9% from 18,481 Gg $CO_2$-eq in 1990 to 16,856 Gg $CO_2$- eq 2020, with highs and lows attributable to irregular extents of natural wildfires between the years. The share of GHG emissions from the AFOLU sector out of total national emissions regressed from 94% in 1990 to 80% in 2016.

Energy emissions increased from 1,117 Gg $CO_2$-eq (6.0%) of national emissions in 1990 to 3,791 Gg $CO_2$- eq (18%) in 2016 as depicted in Table ES1. During the period 1990 to 2016, emissions more than tripled.

The contribution of the IPPU sector in total national emissions increased from 21 Gg $CO_2$-eq in 1990 to a peak of 482 Gg $CO_2$-eq in 2015 to regress to 401 Gg $CO_2$-eq in 2016 (Table ES1). The very sharp increase in GHG emissions in the IPPU sector is due to the commencement of the production of Zinc in 2003 and cement in 2011.

Waste emissions on the other hand increased steadily but slowly over this period, from the 1990 level of 73 Gg $CO_2$-eq to 167 Gg $CO_2$-eq in 2016, representing a 130% increase.

In 2016, Energy contributed 18% of emissions, IPPU 2%, AFOLU 79% and Waste 1%.

**Table ES1 - National GHG emissions (Gg, $CO_2$-eq) by sector (1990 - 2016)**

| Year | Total emissions | Energy | IPPU | AFOLU | Waste |
|---|---|---|---|---|---|
| 1990 | 19,692 | 1,117 | 21 | 18,481 | 73 |
| 1991 | 19,775 | 1,200 | 21 | 18,478 | 76 |
| 1992 | 19,495 | 1,275 | 22 | 18,120 | 79 |
| 1993 | 19,072 | 1,373 | 23 | 17,595 | 81 |
| 1994 | 18,921 | 1,488 | 23 | 17,328 | 82 |
| 1995 | 18,791 | 1,497 | 30 | 17,183 | 81 |
| 1996 | 18,482 | 1,590 | 35 | 16,777 | 80 |
| 1997 | 18,490 | 1,641 | 41 | 16,726 | 82 |
| 1998 | 18,547 | 1,783 | 46 | 16,633 | 85 |
| 1999 | 18,609 | 1,918 | 51 | 16,551 | 89 |
| 2000 | 18,787 | 1,960 | 55 | 16,678 | 94 |
| 2001 | 19,222 | 2,142 | 58 | 16,927 | 95 |
| 2002 | 18,462 | 2,190 | 64 | 16,112 | 96 |
| 2003 | 18,834 | 2,482 | 70 | 16,176 | 106 |
| 2004 | 18,618 | 2,549 | 81 | 15,879 | 108 |
| 2005 | 19,030 | 2,699 | 123 | 16,095 | 114 |
| 2006 | 20,098 | 2,853 | 124 | 17,004 | 116 |
| 2007 | 20,596 | 2,938 | 129 | 17,415 | 113 |
| 2008 | 19,294 | 2,788 | 129 | 16,256 | 121 |
| 2009 | 21,423 | 2,873 | 132 | 18,289 | 129 |
| 2010 | 20,589 | 2,963 | 126 | 17,365 | 135 |
| 2011 | 22,581 | 2,832 | 281 | 19,326 | 142 |
| 2012 | 23,424 | 3,041 | 356 | 19,875 | 152 |
| 2013 | 19,750 | 2,900 | 406 | 16,291 | 153 |
| 2014 | 21,147 | 3,276 | 443 | 17,271 | 157 |
| 2015 | 21,089 | 3,587 | 482 | 16,856 | 165 |
| 2016 | 21,260 | 3,791 | 401 | 16,902 | 167 |

## Emissions by gas

The share of emissions by gas did not change during the period 1990 to 2016. The main contributor to the national GHG emissions remained $CO_2$ followed by $CH_4$ and $N_2O$. However, the share of $CO_2$ increased while those of $CH_4$ and $N_2O$ regressed over the time series. Halogenated gases crept in as from 1993 with a slight increase over the period under review. In 2016, the share of the GHG emissions was as follows: 64% $CO_2$, 22% $CH_4$, 13% $N_2O$ and 1% halogenated gases. The trend of the aggregated emissions and removals by gas is given in Table ES2 and Figure ES4.

**Table ES2 - National GHG emissions and removals (Gg $CO_2$-eq) by gas (1990 - 2016)**

| Year | Total emissions ($CO_2$-eq) | Removals ($CO_2$) | $CO_2$ | $CH_4$ ($CO_2$-eq) | $N_2O$ ($CO_2$-eq) | Halogenated gases ($CO_2$-eq) |
|---|---|---|---|---|---|---|
| 1990 | 19,692 | -90,021 | 9,801 | 6,633 | 3,258 | - |
| 1991 | 19,775 | -91,794 | 9,882 | 6,625 | 3,268 | - |

| Year | Total emissions ($CO_2$-eq) | Removals ($CO_2$) | $CO_2$ | $CH_4$ ($CO_2$-eq) | $N_2O$ ($CO_2$-eq) | Halogenated gases ($CO_2$-eq) |
|---|---|---|---|---|---|---|
| 1992 | 19,495 | -93,706 | 9,956 | 6,390 | 3,150 | - |
| 1993 | 19,072 | -95,488 | 10,053 | 6,043 | 2,975 | 0.2 |
| 1994 | 18,921 | -97,288 | 10,166 | 5,862 | 2,893 | 0.3 |
| 1995 | 18,791 | -99,105 | 10,174 | 5,752 | 2,859 | 6 |
| 1996 | 18,482 | -100,940 | 10,266 | 5,482 | 2,723 | 11 |
| 1997 | 18,490 | -102,793 | 10,316 | 5,439 | 2,719 | 16 |
| 1998 | 18,547 | -104,845 | 10,456 | 5,376 | 2,695 | 20 |
| 1999 | 18,609 | -106,748 | 10,589 | 5,319 | 2,677 | 24 |
| 2000 | 18,787 | -108,809 | 10,629 | 5,392 | 2,737 | 28 |
| 2001 | 19,222 | -109,091 | 11,021 | 5,417 | 2,752 | 32 |
| 2002 | 18,462 | -113,365 | 11,109 | 4,820 | 2,497 | 36 |
| 2003 | 18,834 | -113,824 | 11,356 | 4,897 | 2,541 | 40 |
| 2004 | 18,618 | -115,598 | 11,425 | 4,689 | 2,457 | 47 |
| 2005 | 19,030 | -113,368 | 11,570 | 4,856 | 2,515 | 89 |
| 2006 | 20,098 | -109,749 | 11,720 | 5,482 | 2,805 | 91 |
| 2007 | 20,596 | -106,971 | 11,805 | 5,741 | 2,957 | 93 |
| 2008 | 19,294 | -115,558 | 11,660 | 4,970 | 2,578 | 86 |
| 2009 | 21,423 | -103,774 | 11,741 | 6,391 | 3,206 | 86 |
| 2010 | 20,589 | -107,920 | 11,825 | 5,760 | 2,921 | 85 |
| 2011 | 22,581 | -106,002 | 12,673 | 6,503 | 3,315 | 90 |
| 2012 | 23,424 | -105,021 | 12,952 | 6,871 | 3,509 | 91 |
| 2013 | 19,750 | -122,901 | 12,857 | 4,421 | 2,377 | 95 |
| 2014 | 21,147 | -120,007 | 13,258 | 5,105 | 2,683 | 101 |
| 2015 | 21,089 | -122,078 | 13,587 | 4,804 | 2,585 | 113 |
| 2016 | 21,260 | -126,688 | 13,700 | 4,775 | 2,665 | 120 |

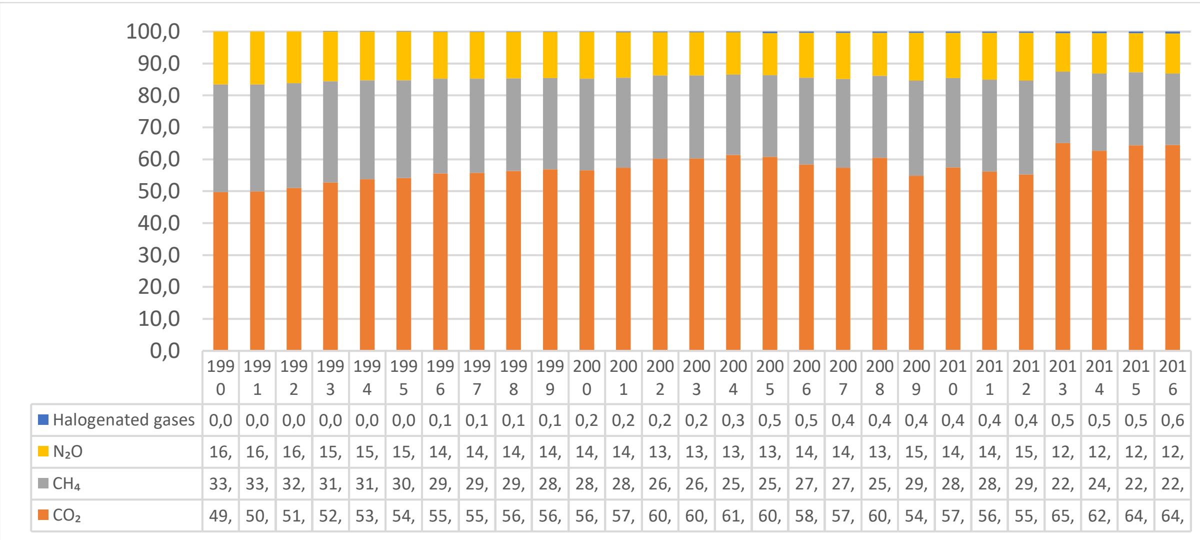


**Figure ES4 - Share of aggregated emissions (%) by gas (1990 - 2016)**

Emissions of indirect GHGs (CO, $NO_x$ and NMVOC) and $SO_2$, have also been estimated and reported in this inventory. Indirect GHGs have not been included in national total emissions. Emissions of these gases for the period 1990 to 2016 are given in Table ES3.

Emissions of $NO_x$ decreased from 52 Gg in the year 1990 to 35.1 Gg in 2016. CO emissions also regressed, from 2,677 Gg in 1990 to 446 Gg in 2016. Emissions of NMVOCs increased from 17 Gg in 1990 to 28 Gg in 2016 whilst emissions of $SO_2$ varied between 1.9 Gg and 4.3 Gg during the same period.

**Table ES3 - Emissions (Gg) of GHG precursors and $SO_2$ (1990 - 2016)**

| Year | $NO_x$ | CO | NMVOCs | $SO_2$ |
|---|---|---|---|---|
| 1990 | 52.0 | 2,676.9 | 16.6 | 1.9 |
| 1991 | 51.1 | 2,556.7 | 17.4 | 2.1 |
| 1992 | 49.9 | 2,436.1 | 17.4 | 2.2 |
| 1993 | 49.3 | 2,322.6 | 17.1 | 2.4 |
| 1994 | 48.9 | 2,208.2 | 17.4 | 2.7 |
| 1995 | 45.6 | 2,092.8 | 17.5 | 2.2 |
| 1996 | 44.3 | 1,976.6 | 17.7 | 2.2 |
| 1997 | 42.0 | 1,859.2 | 18.3 | 2.0 |
| 1998 | 41.9 | 1,741.1 | 19.1 | 2.3 |
| 1999 | 41.7 | 1,622.0 | 19.9 | 2.6 |
| 2000 | 39.6 | 1,475.4 | 21.3 | 2.3 |
| 2001 | 41.2 | 1,488.7 | 21.2 | 2.5 |
| 2002 | 37.6 | 1,143.0 | 20.9 | 2.8 |
| 2003 | 39.4 | 1,151.0 | 21.7 | 3.1 |
| 2004 | 37.5 | 1,035.4 | 22.1 | 3.6 |
| 2005 | 41.7 | 1,278.1 | 22.0 | 3.8 |
| 2006 | 46.2 | 1,629.9 | 23.0 | 4.3 |
| 2007 | 49.9 | 1,915.8 | 23.1 | 4.1 |
| 2008 | 37.9 | 1,212.3 | 23.1 | 4.3 |
| 2009 | 56.0 | 2,275.6 | 23.6 | 3.8 |
| 2010 | 52.2 | 1,958.5 | 23.7 | 3.1 |
| 2011 | 53.5 | 2,089.6 | 24.8 | 3.1 |
| 2012 | 57.2 | 2,178.9 | 25.9 | 3.9 |
| 2013 | 31.7 | 669.8 | 24.5 | 2.6 |
| 2014 | 39.2 | 951.5 | 26.6 | 2.9 |
| 2015 | 39.5 | 799.9 | 26.5 | 3.0 |
| 2016 | 35.1 | 445.9 | 28.3 | 3.6 |

## Summary results for the year 2016

The summary results from the software are presented in this report for the year 2016. The full sets for the whole time series 1990 to 2016 are available in Part 2 of this NIR5 report.

The following findings are based on the 2016 compilations:

(i) most $CO_2$ were emitted in the AFOLU sector at 9,770 Gg. Concurrently, this sector also acted as a sink of 126,688 Gg, to be a net sink of 112,988 Gg for the year 2016. The Energy sector came next with emissions of 3,649 Gg.

(ii) $CH_4$ also emanated mainly from the AFOLU sector followed by the Waste sector. Emissions were 218 Gg and 6.5 Gg for the year 2016 for these two sectors respectively. The Energy sector was responsible for 3.1 Gg of $CH_4$ emissions in 2016.

(iii) $N_2O$ emissions, 8.6 Gg, were primarily associated with the AFOLU sector which contributed more than 96% of national emissions of this gas.

(iv) Among the indirect GHGs, the AFOLU sector was the highest emitter of CO at 78.3% of national emissions with 349.3 Gg, followed by Energy with 87.9 Gg (19.7%) and Waste with

8.7 Gg (2.0%). Energy emitted 29.1 Gg of $NO_x$ emissions and AFOLU was responsible for 5.4 Gg. The Energy and AFOLU sectors contributed 11.5 Gg and 13.5 Gg of total NMVOCs emissions which stood at around 28.3 Gg.

(v) $SO_2$ emissions totalled 3.6 Gg. Emissions from the Energy sector represented more than 99% of national emissions while the remainder emanated from the Waste sector.

## ES 9. QA/QC

Namibia has its own national system for Quality Control (QC) of data which are collected within the different institutions. All data are quality controlled at different stages of the process until the final QA is made by the National Statistics Agency before archiving in national databases. The private sector also implements its own QC/QA within its data collection and archiving process. Thus, the initial phases of the control system remained beyond the GHG inventory compiler and the QA/QC process for the inventory started as from the time the AD are received.

QC and QA procedures, as defined in the *2006 IPCC Guidelines (IPCC, 2006)*, have been implemented during the preparation of the inventory. Whenever there were inconsistencies or possible transcription errors, the responsible institution was queried, and the problem discussed and solved. QC was implemented through:

- Routine and consistent checks to ensure data integrity, reliability and completeness;
- Routine and consistent checks to identify errors and omissions;
- Accuracy checks on data acquisition and calculations and the use of approved standardized procedures for emissions calculations; and
- Technical and scientific reviews of data used, methods adopted and results obtained.

Furthermore, the AD were compared with those available on international database such as those of the Food and Agriculture Organisation (FAO), the United Nations (UN) statistical database and the International Energy Agency (IEA). Namibia is yet to develop and implement a QC management system and this is one of the improvements contemplated in the future.

QA was undertaken by independent reviewers who were not involved with the compilation of the inventory, the main objectives being to:

- Confirm data quality and reliability of data used for computing emissions;
- Compare AD with those available on international websites such as FAO and IEA;
- Review the AD and EFs adopted within each source category as a first step; and
- Review and check the calculation steps in the software to ensure accuracy.

Namibia requested the UNFCCC and Global Support Programme to undertake a QA exercise on its inventory compilation process of the BUR3. The main conclusions and recommendations have been partially attended to. The remaining activities are listed below with the status of actions taken:

- Incineration of medical waste is still being implemented;
- Institutional arrangements to ensure annual provision of AD for preparing the inventory are being strengthened;
- Development and implementation of a QC management system is under way but remains a problem due to lack of permanent staff;
- Improvement of AD for the AFOLU sector through production of new maps to generate land use changes, national stock and EFs, possible use of Collect Earth for confirming the assumptions and data used are all in abeyance due to unavailability of financial resources;

- Development of legal arrangements for securing collaboration of other institutions for AD is under study;
- Improved documentation and archiving are being addressed; and
- Capacity building in various areas of inventory compilation is ongoing.

## ES 10. Completeness

The completeness of the inventory was reviewed and one more sub-category within the Energy sector, namely Manufacture of Solid Fuels has been added for the full time series. The survey being conducted to address emissions of $SF_6$ was not completed within the timeframe of this inventory and is continuing.

## ES 11. Uncertainty analysis

For this Inventory, a Tier 1 uncertainty analysis of the aggregated figures as required by the 2006 IPCC Guidelines, Vol. 1 (IPCC, 2007) was performed. Based on the quality of the data and whether the EFs used were defaults or nationally derived, uncertainty levels were assigned for the two parameters and the combined uncertainty calculated. The uncertainty analysis has been performed using the tool available within the 2006 IPCC Software.

The uncertainty in total emissions was estimated using the IPCC tool incorporated in the IPCC Inventory Software for individual years of the time series and the trend with the addition of one year at a time as from 1990 to 2016. Uncertainty levels (+/-) for the individual years of the period 1990 to 2016 varied from 26.8% to 29.4% while the trend assessment when adding one successive year on the base year 1990 for the years 1991 to 2016 ranged from 37.2% to 51.8%. The full set of results from the software is given in Part 2 of this NIR5 report.

## ES 12. Key Category Analysis

The Key Category Analysis also was performed using the tool available within the IPCC Inventory Software for both level and trend assessment. There are four key categories in the quantitative level assessment for the year 2016, three of these from the AFOLU sector, of which enteric fermentation from Agriculture, the other two from Forestry and Other Land Use (FOLU) being Forest land Remaining Forest land and the last one is Road Transportation from the Energy sector.

The results change quite drastically when considering the trend assessment covering the period 1990 to 2016. There are now nine key categories compared to the level assessment with four only. The four key categories under level assessment recur in the trend assessment also (Table ES4).

**Table ES4. Summary of Key Categories for level (2016) and trend (1990 to 2016) assessments**

| Number | IPCC category code | IPCC category | GHG | Identification criteria | Comment |
|---|---|---|---|---|---|
| 1 | 3.B.1.a | Forest land Remaining Forest land | $CO_2$ | L1,T1 | Quantitative |
| 2 | 3.B.3.b | Land Converted to Grassland | $CO_2$ | L1,T1 | Quantitative |
| 3 | 3.A.1 | Enteric Fermentation | $CH_4$ | L1,T1 | Quantitative |
| 4 | 1.A.3.b | Road Transportation | $CO_2$ | L1,T1 | Quantitative |
| 5 | 3.B.1.b | Land Converted to Forest land | $CO_2$ | T1 | Quantitative |
| 6 | 3.C.1 | Emissions from biomass burning | $CH_4$ | T1 | Quantitative |
| 7 | 3.C.4 | Direct N2O Emissions from managed soils | $N_2O$ | T1 | Quantitative |
| 8 | 3.C.1 | Emissions from biomass burning | $N_2O$ | T1 | Quantitative |
| 9 | 1.A.4 | Other Sectors - Liquid Fuels | $CO_2$ | T1 | Quantitative |

**Notation keys: L = key category according to level assessment; T = key category according to trend assessment; and Q = key category according to qualitative criteria. The Approach used to identify the key category is included as L1, L2, T1 or T2.**

## ES 13. Archiving

All AD collected for the inventory have been stored in the IPCC Inventory Software database after being processed and formatted for making estimates of emissions and removals. All documentation on the data processing and formatting have been kept in soft copies in the excel sheets with the summaries reported in the NIR5. These versions will be managed in electronic format in at least three copies, two stored at the Ministry of Environment and Tourism and a third copy at the National Statistics Agency.

## ES 14. Constraints and needs

Namibia is still facing some challenges to generate reports, including the inventory component, of the required standard to the Convention. To reduce uncertainties and aim at producing an inventory in line with TACCC principles, Namibia is currently reviewing its national GHG inventory management system and institutional arrangements with support from the Secretariat. One major challenge for estimating emissions for the period 1990 to 1999 consisted of the numerous gaps in AD. The latter were not readily available since the country was still setting up its national statistics system after gaining independence. Thus, most of the AD for this period were sourced from international databases or extrapolated based on AD available for the period 2000 to 2016.

## ES 15. National inventory improvement plan (NIIP)

Based on the constraints, gaps and other challenges encountered during the preparation of the inventory, a list of the priority improvements has been identified. The main issues are listed below.

- Capacity building of national experts and strengthening of the existing institutional framework within a GHG inventory management system to provide improved coordinated action for a smooth implementation of the GHG inventory cycle for sustainable production of inventories;
- Development an appropriate framework for adequate and proper data capture, QC and validation;
- Setting up of a storage and retrieval mechanism of AD collected to facilitate the compilation of future inventories;
- Development of national EFs more representative of the national context for all key categories;
- Development and implementation of a QA/QC plan to improve the existing QA/QC system to reduce uncertainty and improve inventory quality;
- Access the necessary financial resources to establish a GHG inventory unit within Department of Environmental Affairs (DEA) to be responsible for sustainable inventory compilation;
- Institutionalize the archiving system;
- Completion of surveys for collecting the required AD on the use of $SF_6$ and incineration of medical waste;
- Undertake new forest inventories to confirm the stock and EFs generated for the Land sector based on published scientific work;
- Produce new maps for 1990 to 2016 to refine land use change data over 5 years periods to replace the low-quality maps available now;
- Refine data collection for determining country-specific (CS) weights for dairy cows, other cattle, sheep and goats; and
- Develop the digestible energy (DE) factor for livestock as CS data is better than the default IPCC value to address this key category fully at Tier 2.

# 1. Introduction

## 1.1. Commitments under the Convention

The UNFCCC was adopted in 1992 at the UN Conference on Environment and Sustainable Development in Rio de Janeiro, Brazil. The Convention came into force on 21 March 1994. The Republic of Namibia ratified the Convention on 16 May 1995 as a Non-Annex 1 Party and this decision came into effect on 14 August 1995.

Under Article 4.1 (a) of the Convention, each party has to develop, periodically update, publish and make available to the COP, in accordance with Article 12, national inventories of anthropogenic emissions by sources and removals by sinks of all GHGs not controlled by the Montreal Protocol, to the extent its capacities permit, using comparable methodologies to be promoted and agreed upon by the COP.

Moreover, the submissions should also include the following elements amongst others:

a. A general description of steps taken or envisaged by the Party to implement the Convention; and
b. Any other information that the Party considers relevant to the achievement of the objective of the convention and suitable for inclusion in its communication, including, if feasible, material relevant for calculations of global emission trends

In order to meet its reporting obligations, Namibia has submitted four national communications (NCs) and three Biennial Update Reports (BURs), the Republic of Namibia being the first developing country to submit its BUR in 2014. In line with the new reporting requirements, Namibia has presented its last four inventories as stand-alone reports NIR1 to NIR4 for maximizing transparency as advocated under the Paris Agreement. Thus, Namibia has to-date submitted seven GHG inventories detailing its emissions and sinks as components of its national communications and BURs. Namibia has now prepared its eighth national inventory in the best possible transparent manner and reporting the findings in the NIR5 and as a chapter in the fourth BUR along with other actions taken to implement the Convention. All these reports have been prepared with support from the GEF through UNDP.

Additionally, Namibia has prepared and submitted its Intended Nationally Determined Contributions (INDCs) during COP 21 in Paris. The country signed and ratified the Paris Agreement on 22 April 2016 and 21 September 2016 respectively. Namibia is also currently updating its NDC.

# 2. The inventory process

## 2.1. Overview of GHG inventories

The preparation of the present inventory started in 2018 after completion of the one contained in the BUR3. One year was allocated to implement and complete the different steps of the inventory cycle as depicted in Figure 2.1. Funding under the climate change programme of the GEF through its implementing agency, the UNDP, provided the financial support for the preparation of this seventh national GHG inventory reported in the NC4.

The NC1 and NC2 of the Republic of Namibia to the UNFCCC included the National Inventory of GHGs for base years 1994 and 2000. These inventories were compiled at Tier 1 level using the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 1997). These inventories have all been compiled using the sectoral bottom-up approach. The reference approach has also been used for the Energy sector, to enable comparison of the two methods. The gases estimated were $CO_2$, $CH_4$, $N_2O$, HFCs and the and the precursor gases $NO_x$, $SO_2$, NMVOCs and CO. A third Inventory has been compiled using a mix of Tiers 1 and 2 for BUR1 and submitted to the UNFCCC in 2014. The latest four inventories have been submitted as stand-alone NIRs. The IPCC 2006 Guidelines and software were used for compiling these inventories.

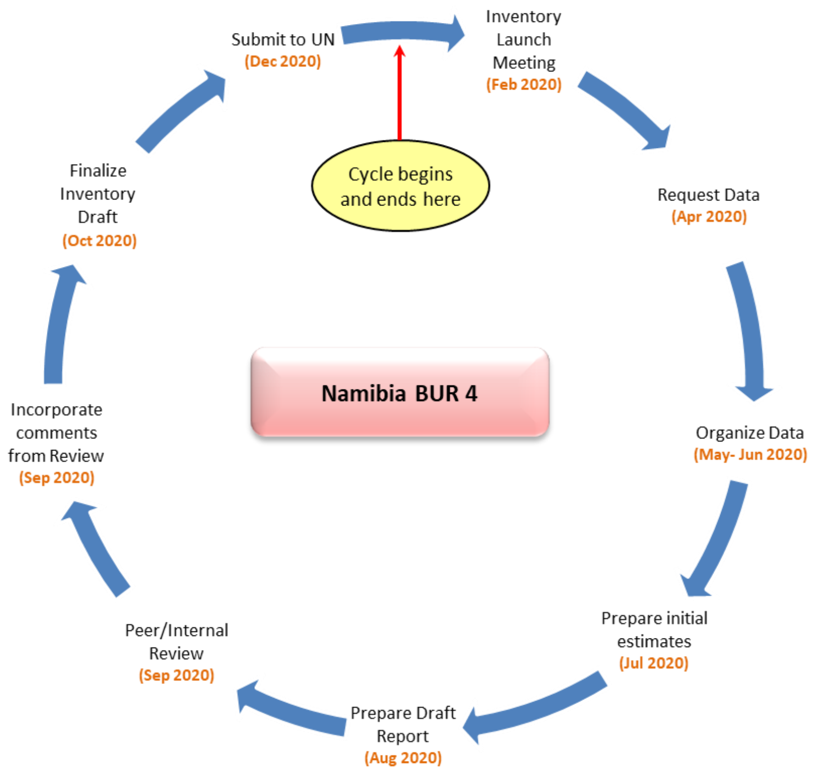


**Figure 2.1 - The inventory cycle of Namibia's BUR4**

This eighth GHG inventory is presented as a chapter of the BUR4 and as a stand-alone NIR5 and provides data on GHG emissions by sources and removals by sinks for a full time series for the period 1990 to 2016, the years 1990 and 2016 being additions to the previous one. Improvements over the previous inventory consisted in the inclusion of the sub-category Manufacture of Solid Fuels. Once again, a mix of Tiers 1 and 2 has been adopted.

## 2.2. Institutional arrangements and inventory preparation

Namibia consolidated the in-house production of its GHG inventory. However, due to lack of financial resources to maintain permanent staff for a full institutionalization of the process, the country had to outsource the computation of emissions and report writing to a company and the services of an independent international consultant were hired for performing the QA and capacity building to meet the enhanced transparency and higher standards of reporting. Furthermore, the upfront segment of the process is a laborious exercise as sufficient financial resources to support adequate human capacity remains a prominent limiting factor. Another constraining factor concerns the numerous changes in the working groups following staff movements, promotions and resignations.

The CCU of the Ministry of Environment and Tourism monitors and coordinates the production of reports to the Convention, including the GHG inventories as National Focal Point of the Convention. The same framework adopted for the previous inventory (NIR3) compilation was followed. Collaboration with data providers, institutions and organizations to support derivation of national EFs and enable moving to Tier 2 were consolidated. Capacity building of the inventory working group members continued.

The institutional arrangements for the compilation of the inventory and reporting for the different sectors are shown in Figure 2.2.

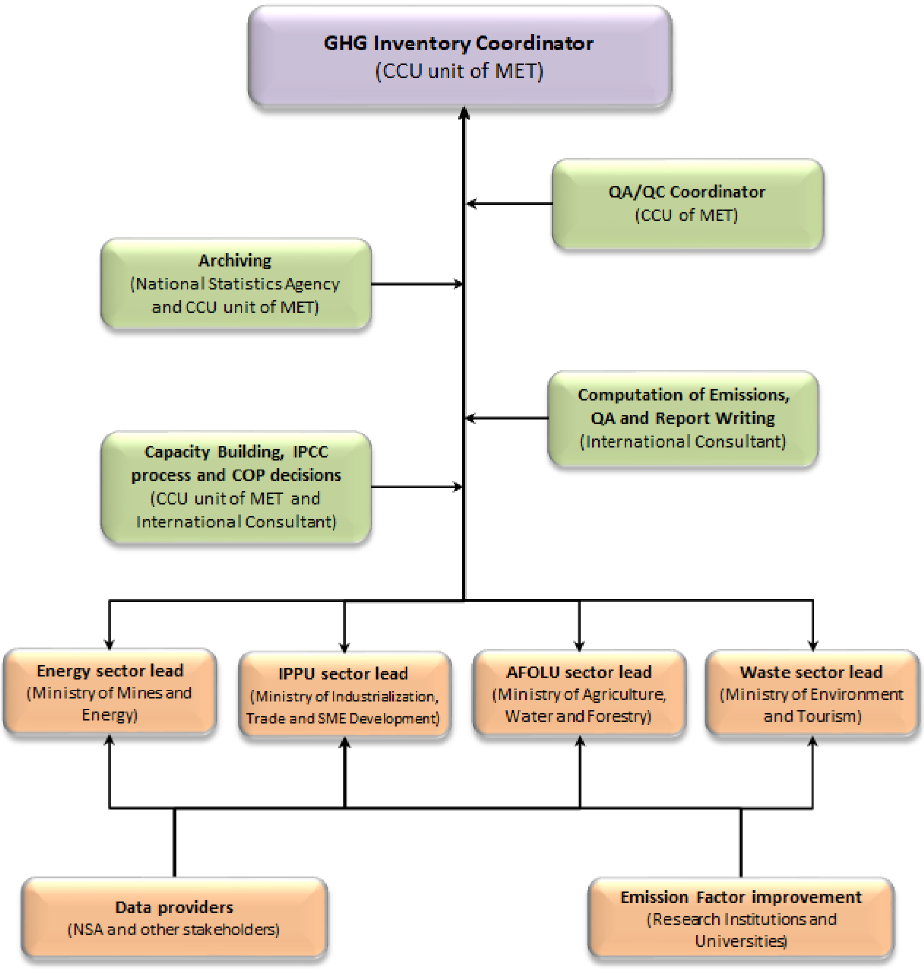


Figure 2.2 - Institutional arrangements for the GHG inventory preparation

The responsibilities within the institutional arrangements remained unchanged as follows:

- The CCU of Ministry of Environment and Tourism for inventory coordination, compilation and submission;
- Ministry of Mines and Energy for the Energy sector;
- Ministry of Industrialization, Trade and SME Development for the Industrial Production and Product Use sector;
- Ministry of Agriculture, Water Affairs and Forestry (MAWF) for Agriculture, Forest and Other Land Use sector;
- The Ministry of Environment and Tourism for the Waste sector;
- Namibia National Statistics Agency for archiving, including provision of quality-controlled AD;
- The CCU of Ministry of Environment and Tourism for coordinating QA/QC;
- External consultant for capacity building and QA;
- The CCU of Ministry of Environment and Tourism for coordinating Uncertainty Analysis; and
- The CCU of Ministry of Environment and Tourism to act as GHG inventory specialist to track capacity building needs, the IPCC process and COP decisions for implementation.

The different steps adopted for the preparation of the inventory were:

- Drawing up of work plan with timeline and deliverables;
- Allocation of tasks to sectoral experts;
- Collection, quality control and validation of AD;
- Selection of Tier level within each category and sub-category;
- Selection of EFs and Derivation of local EFs wherever possible;
- Validation of AD and EFs during a workshop serving for capacity building concurrently;
- Computation of GHG emissions;
- Uncertainty analysis;
- QA/QC of emissions and outputs;
- Assessment of completeness;
- Recalculations;
- Trend analysis;
- Identification of Gaps, constraints, needs and improvements;
- Report writing.
- Circulation of report to stakeholders for comments;
- Integration of stakeholder’s comments;
- Validation of GHG inventory and chapter for inclusion in BUR4; and
- Submission to UNFCCC as a stand-alone NIR and a component of the BUR4

## 2.3. Key Category Analysis

Key Category Analysis (KCA) gives the characteristics of the emission sources and sinks. According to the *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000), key categories are those which contribute 95% of the total annual emissions, when ranked from the largest to the smallest emitter. Alternatively, a key source is one that is prioritized within the national inventory system because its estimate has a significant influence on a country's total inventory of direct GHGs in terms of the absolute level of emissions, the trend in emissions, or both (IPCC, 2000). Thus, it is a good practice to identify key categories, as it helps prioritize efforts and improve the overall quality of the national inventory, notwithstanding guiding of mitigation policies, strategies and actions.

The KCA was performed using the tool available within the IPCC Inventory Software for both the level and trend assessments. The results for the level assessment for the year 2016 are presented in Table 2.1 and for the year 1990 in Table 2..

**Table 2.1 - Key Category Analysis for the year 2016 - Approach 1 - Level Assessment**

| A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|
| IPCC Category code | IPCC Category | GHG | "2015 Ext. (Gg $CO_2$-eq)" | "\|exit\| (Gg $CO_2$-eq)" | Lx,t | Cumulative Total of Column F |
| 3.B.1.a | Forest land Remaining Forest land | $CO_2$ | -125,635 | 125,635 | 0.851 | 0.851 |
| 3.B.3.b | Land Converted to Grassland | $CO_2$ | 9,756 | 9,756 | 0.066 | 0.917 |
| 3.A.1 | Enteric Fermentation | $CH_4$ | 4,000 | 4,000 | 0.027 | 0.944 |
| 1.A.3.b | Road Transportation | $CO_2$ | 2,779 | 2,779 | 0.019 | 0.963 |

**Table 2.2 - Key Category Analysis for the year 1990 - Approach 1 - Level Assessment**

| A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|
| IPCC Category code | IPCC Category | GHG | "2015 Ex,t (Gg $CO_2$-eq)" | "\|Ex,t\| (Gg $CO_2$-eq)" | Lx,t | Cumulative Total of Column F |
| 3.B.1.a | Forest land Remaining Forest land | $CO_2$ | -88,401 | 88,401 | 0.806 | 0.806 |
| 3.B.3.b | Land Converted to Grassland | $CO_2$ | 8,672 | 8,672 | 0.079 | 0.885 |
| 3.C.1 | Emissions from Biomass Burning | $CH_4$ | 3,594 | 3,594 | 0.033 | 0.917 |
| 3.A.1 | Enteric Fermentation | $CH_4$ | 2,878 | 2,878 | 0.026 | 0.944 |
| 3.B.1.b | Land converted to Forestland | $CO_2$ | -1,620 | 1,620 | 0.015 | 0.958 |

There are four key categories in the quantitative level assessment for the year 2016 as opposed to five for the year 1990. All of these for both years were from the AFOLU sector except for Road Transportation in 2016, of which enteric fermentation from Agriculture and the others from FOLU being Forest land Remaining Forest land and the last one is Road Transportation from the Energy sector.

The results change quite drastically when considering the trend assessment covering the period 1990 to 2016 (Table 2.). There are now nine key categories compared to the level assessment with four only.

**Table 2.3 - Key Category Analysis for the period 1990 - 2016 - Approach 1 - Trend Assessment**

| A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|
| IPCC Category code | IPCC Category | GHG | 1991 Year Estimate Ex0 (Gg $CO_2$-eq) | 2015 Year Estimate Ext (Gg $CO_2$-eq) | Trend Assessment (Txt) | % Contribution to Trend | Cumulative Total of Column G |
| 3.B.1.a | Forest land Remaining Forest land | $CO_2$ | -88,401 | -125,635 | 0.066 | 0.304 | 0.304 |
| 3.B.3.b | Land Converted to Grassland | $CO_2$ | 8,672 | 9,756 | 0.050 | 0.229 | 0.532 |
| 3.A.1 | Enteric Fermentation | $CH_4$ | 2,878 | 4,000 | 0.023 | 0.108 | 0.640 |
| 1.A.3.b | Road Transportation | $CO_2$ | 527 | 2,779 | 0.023 | 0.106 | 0.746 |
| 3.B.1.b | Land Converted to Forest land | $CO_2$ | -1,620 | -963 | 0.013 | 0.062 | 0.808 |
| 3.C.1 | Emissions from biomass burning | $CH_4$ | 3,594 | 479 | 0.012 | 0.055 | 0.863 |
| 3.C.4 | Direct $N_2O$ Emissions from managed soils | $N_2O$ | 1,441 | 2,015 | 0.012 | 0.055 | 0.917 |
| 3.C.1 | Emissions from biomass burning | $N_2O$ | 1,575 | 209 | 0.005 | 0.024 | 0.941 |
| 1.A.4 | Other Sectors - Liquid Fuels | $CO_2$ | 347 | 380 | 0.002 | 0.009 | 0.950 |

The summary of Key Categories based on the quantitative level to the 95% level assessments for year 2016 and trend, for period 1990 to 2016, is presented in Table 2.. The number of Key categories increased from four under level assessment to nine with the four main ones recurring in the trend assessment also.

**Table 2.4 - Summary of Key Categories for level (2016) and trend (1990 - 2016) assessments**

| Number | IPCC category code | IPCC category | GHG | Identification criteria | Comment |
|---|---|---|---|---|---|
| 1 | 3.B.1.a | Forest land Remaining Forest land | $CO_2$ | L1,T1 | Quantitative |
| 2 | 3.B.3.b | Land Converted to Grassland | $CO_2$ | L1,T1 | Quantitative |
| 3 | 3.A.1 | Enteric Fermentation | $CH_4$ | L1,T1 | Quantitative |
| 4 | 1.A.3.b | Road Transportation | $CO_2$ | L1,T1 | Quantitative |
| 5 | 3.B.1.b | Land Converted to Forest land | $CO_2$ | T1 | Quantitative |
| 6 | 3.C.1 | Emissions from biomass burning | $CH_4$ | T1 | Quantitative |
| 7 | 3.C.4 | Direct N2O Emissions from managed soils | $N_2O$ | T1 | Quantitative |
| 8 | 3.C.1 | Emissions from biomass burning | $N_2O$ | T1 | Quantitative |
| 9 | 1.A.4 | Other Sectors - Liquid Fuels | $CO_2$ | T1 | Quantitative |

**Notation keys: L = key category according to level assessment; T = key category according to trend assessment; and Q = key category according to qualitative criteria. The Approach used to identify the key category is included as L1, L2, T1 or T2.**

## 2.4. Methodological issues

This section gives an overview of the methodological approach adopted for all sectors and sub-sectors covered in this inventory report. These procedures are extensively detailed in the respective section covering the individual IPCC Key Categories.

Generally, the method adopted to compute emissions involved multiplying activity data (AD) by the relevant appropriate emission factor (EF), as shown below:

**Emissions (E) = Activity Data (AD) x Emission Factor (EF)**

All the methods and tools recommended by IPCC for the computation of emissions in an inventory have been used and followed to be in line with Good Practices. The IPCC 2006 Guidelines were supplemented with the EMEP/EEA Guidebook 2016 for estimation of emissions of non-$CO_2$ gases. Equations from the Guidebook were programmed in Excel, estimations made and entered manually in the sectoral tables generated by the IPCC Inventory Software for reporting in the NIR5.

The Tier 2 method has been adopted for estimating emissions in the Road Transportation (1.A.3.b) sector where the vehicle population has been disaggregated in different classes coupled with mileage run annually and consumption per vehicle class. Additionally, national EFs and stock factors as appropriate have been derived and adopted to compile estimates at the Tier 2 level partially for Enteric Fermentation (3.A.1) for Dairy Cows and Other Cattle in the Livestock and Forest land Remaining Forest land (3.B.1.a) in the AFOLU sector. Thus, the inventory has been compiled using a mix of Tiers 1 and 2. This is good practice and improved the accuracy of the emission estimates of most of the key categories and reduced the uncertainty level.

GWP as recommended by the IPCC have been used to convert GHGs other than $CO_2$ to the latter equivalent. Based on decision 17/CP.8, the values adopted were those from the IPCC Second Assessment Report for all direct GHGs, namely $CO_2$, $CH_4$ and $N_2O$ as well as HFCs used for Refrigeration and Air Conditioning (Table 2.). Additional gases, known as (indirect gases), which affect global warming, namely $NO_x$, CO, NMVOCs and $SO_2$, have also been computed and reported in the inventory.

**Table 2.5 - Global Warming Potential**

| Gas | Symbol | Global Warming Potential |
|---|---|---|
| Carbon Dioxide | ($CO_2$) | 1 |
| Methane | ($CH_4$) | 21 |
| Nitrous Oxide | ($N_2O$) | 310 |
| HFC - 32 | (CH2F2) | 650 |
| HFC - 125 | (CH2CF3) | 2,800 |
| HFC - 134a | (CF2FCF3) | 1,300 |
| HFC - 143a | (CF3CH3) | 3,800 |

Default EFs were assessed for their appropriateness prior to their adoption; namely based on the situations under which they have been developed and the extent to which these were representative of national circumstances. Country-specific EFs and stock factors derived using national data and the IPCC equations as appropriate for the Livestock and Land sub-sectors were used instead of the default ones which did not reflect the national context.

Country-specific AD are readily available as a fairly good statistical system exists since 2003 whereby data pertaining to most of the socio-economic sectors are collected, verified and processed to produce official national statistics reports. Additional and/or missing data, and those required to meet the level of disaggregation for higher than the Tier 1 level, were sourced directly from both public and private sector operators by the working groups and coordinator. Data gaps were filled through personal contacts with the stakeholders by the national experts and/or from results of surveys, scientific studies and by statistical modelling. All the data and information collected during the inventory process have been stored in the software database.

In some cases, due to the restricted timeframe and lack of a declared National framework for data collection and archiving to meet the requirements for preparing GHG inventories, derived data and estimates were used to fill in the gaps. These were considered reliable and sound since they were based on scientific findings and other observations. Estimates used included fuel use for navigation, domestic aviation, food consumption and forest areas by type. Most AD for the period 1991 to 2002 were generated based on related socio-economic factors or through extrapolations from the available time series AD.

## 2.5. Quality Assurance and Quality Control (QA/QC)

Namibia has its own national system for QC of data collected within the different institutions. All data are quality controlled at different stages of the process until the final QA is made by the National Statistics Agency before archiving in national databases. The private sector also implements its own QC/QA within its data collection and archiving process. Thus, the initial phases of the control system remained beyond the GHG inventory team and the QA/QC process started as from the time the AD are received.

QC and QA procedures, as defined in the *2006 IPCC Guidelines (IPCC, 2006)* have been implemented during the preparation of the inventory. Whenever there were inconsistencies or possible transcription errors, the responsible institution was queried, the problem discussed and solved as far as possible. However, this process is not exempt of mistakes because outliers were frequently observed from the time series data for various activities. QC was implemented through:

- Routine and consistent checks to ensure data integrity, reliability and completeness;
- Routine and consistent checks to identify errors and omissions;
- Accuracy checks on data acquisition and calculations and the use of approved standardized procedures for emissions calculations; and
- Technical and scientific reviews of data used, methods adopted, and results obtained.

Furthermore, the AD were compared with those available on international database such as those of FAO, the UN statistical database and the IEA. Namibia is yet to develop and implement a QC management system and this is one of the improvements contemplated in the future.

QA was undertaken by independent reviewers who were not involved with the preparation of the inventory, the main objectives being to:

- Confirm the quality and reliability of data used for computing emissions;
- Compare AD with those available on international websites such as FAO and IEA;
- Review the AD and EFs adopted within each source category as a first step; and
- Review and check the calculation steps in the software to ensure accuracy.

Even if QA/QC procedures have been followed throughout the inventory process by the inventory compilers of the different IPCC sectors and the QA officer, a QA/QC plan has yet to be developed to fit within the domestic Measure, Report and Verify (MRV) system under development. Thus, systematic records as per the *2006 IPCC Guidelines* still must be developed under a dedicated QA/QC coordinator. This resulted from the lack of permanent personnel on the establishment, insufficient capacity and because the inventory management system is still being developed and implemented in the country.

Namibia requested the UNFCCC and Global Support Programme to undertake a QA exercise on its inventory compilation process adopted for the BUR3. The main conclusions and recommendations have been partially attended to. The remaining activities are listed below with the status of actions taken, are:

- Incineration of medical waste is still being implemented;
- Institutional arrangements to ensure annual provision of AD for preparing the inventory are being strengthened;
- Development and implementation of a QC management system is under way but remains a problem due to lack of permanent staff;
- Improvement of AD for the AFOLU sector through production of new maps to generate land use changes, national stock and EFs, possible use of Collect Earth for confirming the assumptions and data used are all in abeyance due to unavailability of financial resources;
- Development of legal arrangements for securing collaboration of other institutions for AD is under study;
- Improved documentation and archiving are being addressed; and
- Capacity building in various areas of inventory compilation is ongoing.

## 2.6. Uncertainty analysis

Uncertainty estimation is an essential element of a complete GHG inventory to provide information on the categories to be prioritized for maximum resources to be allocated to improve the quality of the inventory. Inventories prepared in accordance with *2006 IPCC guidelines* (IPCC, 2007) will typically contain a wide range of emission estimates, varying from carefully measured and demonstrably complete data on emissions to order-of-magnitude estimates of highly variable emissions such as $N_2O$ fluxes from soils and waterways.

For this inventory, a Tier 1 uncertainty analysis of the aggregated figures as required by the *2006 IPCC Guidelines, Vol. 1* (IPCC, 2007) was performed. Based on the quality of the data and whether the EFs used were defaults or nationally derived, uncertainty levels were allocated for the two parameters and the combined uncertainty calculated. In most cases, the uncertainty values allocated to AD and EFs from within the range recommended by the IPCC Guidelines were applied. Thus, lower uncertainties were allocated to AD obtained from measurements made and recorded, higher values for interpolated and extrapolated AD and the highest ones in the range when the AD is subject to expert knowledge. Regarding the EFs, the average value recommended in the IPCC Guidelines were adopted except for nationally determined EFs when the lower values in the range were adopted. Whenever there was a need to revert to expert judgement, the protocol was to consult with more than one expert from the typical sector or industry to ascertain on the level of uncertainty to be adopted from within the range provided in the IPCC guidelines. In cases where IPCC has a particular recommended methodology, the uncertainty level was derived according to the procedure proposed in the IPCC Guideline and used in the uncertainty analysis. The uncertainty analysis has been performed using the tool available within the IPCC Inventory Software. Uncertainties in total emissions based on the IPCC tool including emissions and removals from the Land sector is presented in Table 2.6. Uncertainty levels for the individual years of the period 1990 to 2016 varied from 26.8% to 29.4% while the trend assessment when adding one successive year on the base year 1990 for the years 1991 to 2016 ranged from 37.2% to 51.8%.

**Table 2.6 - Overall uncertainty (%)**

| Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Annual | 28.9 | 28.8 | 28.5 | 28.2 | 28.0 | 27.8 | 27.6 | 27.4 | 27.3 | 27.2 | 27.2 | 27.3 | 26.9 | 27.0 |
| Trend (base year 1990) | | 37.2 | 38.0 | 38.7 | 39.5 | 40.2 | 41.0 | 41.7 | 42.5 | 43.3 | 44.2 | 44.3 | 46.1 | 46.3 |

| Year | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Annual | 26.8 | 27.0 | 27.6 | 28.0 | 27.1 | 28.7 | 28.0 | 29.0 | 29.4 | 27.1 | 27.6 | 27.5 | 27.3 |
| Trend (base year 1990) | 47.0 | 46.1 | 44.6 | 44.0 | 47.0 | 42.1 | 43.9 | 43.3 | 42.9 | 50.2 | 49.0 | 49.9 | 51.8 |

## 2.7. Assessment of completeness

An assessment of the completeness of the inventory was made for individual activity areas within each source category and the results are presented within the sections covering the individual sectors. The methodology adopted was according to the *IPCC 2006 Guidelines (IPCC 2007)* with the following notation keys used:

| | |
|---|---|
| X | Estimated |
| NA | Not Applicable |
| NO | Not Occurring |
| NE | Not Estimated |
| IE | Included Elsewhere |

The level of completeness depicting the scope of the inventory is provided in the national and sectoral reporting tables within the respective sections further in this chapter. In cases where there was no activity for all sub-categories within a category, only the category row is maintained for ease of presentation and understanding.

## 2.8. Recalculations

Recalculations have been performed during the computation of the present inventory whenever new improved datasets were obtained. Only recalculated emissions for the base years 1994, 2000 and 2010 are given in Table 2.7 while for the remaining years of the time series, the recalculations can be captured in the sectoral presentations. Original estimates of 1994, 2000 and 2010 were made according to IPCC 1996 Revised GL, Tier 1 and lower coverage of activity areas compared to the present inventory and default EFs while recalculated values have been compiled in line with the 2006 IPCC GL, a mix of Tiers 1 and 2, the latter for some key categories, improved datasets and a more exhaustive coverage.

**Table 2.7 - Comparison of original and recalculated emissions, removals and net removals of past inventories presented in national communications**

| Year | 1994 | | 2000 | | 2010 | |
|---|---|---|---|---|---|---|
| | INC | BUR4 | SNC | BUR4 | TNC | BUR4 |
| Removals | -5,716 | -97,288 | -10,566 | -108,809 | -28,534 | -107,920 |
| Emissions | 5,685 | 18,921 | 9,118 | 18,787 | 27,195 | 20,589 |
| Net removals | -31 | -78,367 | -1,442 | -90,022 | -1,339 | -87,331 |

## 2.9. Time series consistency

This inventory now covers the period 1990 to 2016 and AD within each of the source categories covered were abstracted from the same sources for all years. The same EFs have been used throughout the full time series and the QA/QC procedures were kept constant for the whole inventory period. This enabled a consistent time series to be built with a good level of confidence in the trends of emissions.

## 2.10. Constraints and needs

Namibia is still facing some challenges to report to the required standard to the Convention, including on the inventory component. To reduce uncertainties and aim at producing an inventory in line with TACCC principles, Namibia is currently reviewing its national GHG inventory management system and institutional arrangements with support from the Secretariat. One major challenge for estimating emissions for the period 1990 to 1999 consisted of the numerous gaps in AD. The latter were not readily available since the country was still setting up its national statistics system after gaining independence. Thus, most of the AD for this period were sourced from international databases or extrapolated based on AD available for the period 2000 to 2016.

For this inventory, one more category, namely emissions from Manufacture of Solid Fuels (production of charcoal from wood) has been included. Some information has also been collected on the use of $SF_6$ and incineration of medical wastes, but unfortunately, they were not sufficient to enable computation of emissions in these categories. Further efforts will be invested to address these categories to make the inventory fully exhaustive in the future.

Problems encountered during the preparation of this national inventory of GHG were:

- Information required for the inventory were obtained from various sources as no institution has yet been endorsed with the responsibility for collection of specific AD needed for the estimation of emissions according to IPCC on an annual basis. Agreements are being formalized to have the sectoral lead institutions to collect AD, QC these AD and submit to Namibia Statistics Agency (NSA) for databasing and archiving;

- A substantial amount of the AD, including those from the NSA are still not yet in the required format for feeding in the software to make the emission estimates;
- End-use consumption data for some of the categories are not readily available and had to be generated based on scientific and consumption parameters;
- Reliable biomass (bm) data such as timber, fuelwood, wood waste and charcoal consumed or produced were not available and had to be derived using statistical modelling of Census data;
- Appropriate information on some activities such as beverage production and auto-production of heat and electricity were not always available as these were not released as considered confidential by the producers;
- Lack of solid waste characterization data, amount generated, and wastewater generated from the industrial sector were only partly available and had to be derived based on production and demographic data amongst others;
- Lack of EFs to better represent national circumstances and provide for more accurate estimates, even if this has started to be addressed for some key categories;
- Emissions for a few categories have not been estimated due to lack of AD; and
- National experts could not take over the full inventory compilation process because of insufficient time available when considering their other responsibilities. This dictated the contracting of an international consultant;

## 2.11. National inventory improvement plan (NIIP)

Based on the constraints, gaps and other challenges encountered during the preparation of the present inventory, a list of the priority improvements has been identified. These are listed below and will be addressed during the preparation of the next NIR. Lack of resources, namely funds and capacity are the major barriers to implementing the NIIP. It is intended to develop a detailed NIIP inclusive of timeframe, costs and other needs along with a schedule for implementation. This document will be used to capture resources for implementing the NIIP to meet the transparency requirements of the Paris Agreement. The main activities of the NIIP are listed below.

- Capacity building and strengthening of the existing institutional framework within a GHG inventory management system to provide improved coordinated action for a smooth implementation of the GHG inventory cycle for sustainable production of inventories;
- Development of an appropriate framework for adequate and proper data capture, QC and validation;
- Setting up of a storage and retrieval mechanism of AD collected to facilitate the compilation of future inventories;
- Development of national EFs more representative of the national context for all key categories;
- Development and implementation of a QA/QC plan to improve the existing QA/QC system to reduce uncertainty and improve inventory quality;

- Access the necessary financial resources to establish a GHG inventory unit within DEA to be responsible for sustainable inventory compilation;
- Institutionalize the archiving system;
- Undertake surveys for collecting the required AD for categories not covered in this exercise, namely the use of $SF_6$ and incineration of medical waste;
- Conduct new forest inventories to confirm the stock and EFs adopted for the Land sector and generated based on published scientific work;
- Produce new maps for 1990 to 2016 to refine land use change data over 5 years periods to replace the low-quality maps available now which are proving inadequate;
- Refine data collection for determining CS weights for dairy cows, other cattle, sheep and goats; and
- Develop the DE factor for livestock as CS data is better than the default IPCC value to address this key category fully at Tier 2.

# 3. Trends of greenhouse gas emissions

## 3.1. Overview

The trends of GHG emissions for the Republic of Namibia cover the period 1990 to 2016. Availability of more disaggregated data enabled the adoption of higher Tier methods, namely a combination of Tiers 1 and 2 for compiling this inventory.

## 3.2. The period 1990 to 2016

Namibia remained a net GHG sink over the period 1990 to 2016 as the Land category removals exceeded emissions from the other categories. The net removal of $CO_2$ increased by 50% over these 27 years from 70,329 Gg in 1990 to 105,428 Gg in 2016. During the same period, the country recorded an increase of 8% in emissions, from 19,692 Gg $CO_2$-eq to 21,260 Gg $CO_2$-eq. The trend for the period 1990 to 2016 indicates that the total removals from the Land category increased from 90,021 Gg $CO_2$-eq in 1990 to 126,688 Gg $CO_2$-eq in 2016 (Table 3.1 and Figure 3.1).

**Table 3.1 - GHG emissions (Gg $CO_2$-eq) characteristics (1990 - 2016)**

| Year | Total emissions | AFOLU removals | Net removals | Per capita emission (t) | GDP emissions index (Year 1990 = 100) |
|---|---|---|---|---|---|
| 1990 | 19,692 | -90,021 | -70,329 | 13.7 | 100.0 |
| 1991 | 19,775 | -91,794 | -72,019 | 13.3 | 92.8 |
| 1992 | 19,495 | -93,706 | -74,211 | 12.8 | 85.4 |
| 1993 | 19,072 | -95,488 | -76,417 | 12.3 | 83.7 |
| 1994 | 18,921 | -97,288 | -78,367 | 11.9 | 77.4 |
| 1995 | 18,791 | -99,105 | -80,314 | 11.6 | 73.8 |
| 1996 | 18,482 | -100,940 | -82,458 | 11.2 | 70.3 |
| 1997 | 18,490 | -102,793 | -84,303 | 11.0 | 67.5 |
| 1998 | 18,547 | -104,845 | -86,298 | 10.8 | 65.6 |
| 1999 | 18,609 | -106,748 | -88,140 | 10.6 | 63.6 |
| 2000 | 18,787 | -108,809 | -90,022 | 10.5 | 62.1 |
| 2001 | 19,222 | -109,091 | -89,869 | 10.5 | 62.8 |
| 2002 | 18,462 | -113,365 | -94,903 | 9.9 | 57.5 |
| 2003 | 18,834 | -113,824 | -94,990 | 10.0 | 56.3 |
| 2004 | 18,618 | -115,598 | -96,980 | 9.8 | 49.6 |
| 2005 | 19,030 | -113,368 | -94,338 | 9.8 | 49.4 |
| 2006 | 20,098 | -109,749 | -89,651 | 10.2 | 48.7 |
| 2007 | 20,596 | -106,971 | -86,375 | 10.3 | 47.4 |
| 2008 | 19,294 | -115,558 | -96,264 | 9.6 | 42.9 |
| 2009 | 21,423 | -103,774 | -82,351 | 10.5 | 48.2 |
| 2010 | 20,589 | -107,920 | -87,331 | 9.9 | 43.6 |
| 2011 | 22,581 | -106,002 | -83,421 | 10.7 | 45.2 |
| 2012 | 23,424 | -105,021 | -81,598 | 10.9 | 44.7 |
| 2013 | 19,750 | -122,901 | -103,151 | 9.0 | 35.7 |
| 2014 | 21,147 | -120,007 | -98,859 | 9.4 | 35.9 |

| Year | Total emissions | AFOLU removals | Net removals | Per capita emission (t) | GDP emissions index (Year 1990 = 100) |
|---|---|---|---|---|---|
| 2015 | 21,089 | -122,078 | -100,989 | 9.2 | 34.3 |
| 2016 | 21,260 | -126,688 | -105,428 | 9.1 | 34.6 |

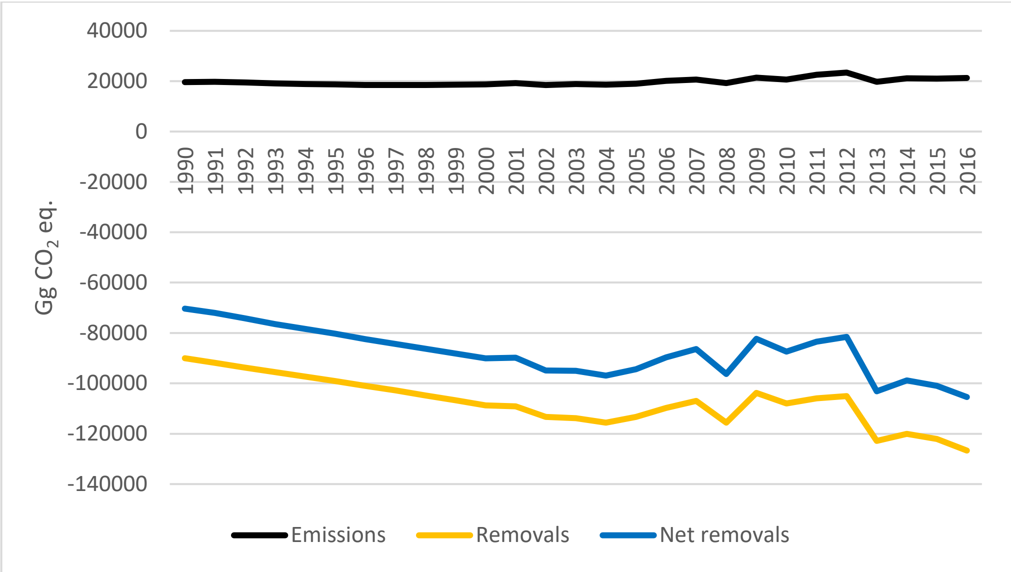


**Figure 3.1 - Evolution of national emissions, national removals and the overall (net) situation (Gg $CO_2$-eq), (1990 - 2016)**

Per capita emissions of GHG decreased gradually from 13.4 tonnes $CO_2$-eq in 1990 to reach 9.1 tonnes in 2016 (Figure 3.2). The GDP emission index decreased almost steadily from 100 in the year 1990 to 35 in 2016 (Figure 3.3).

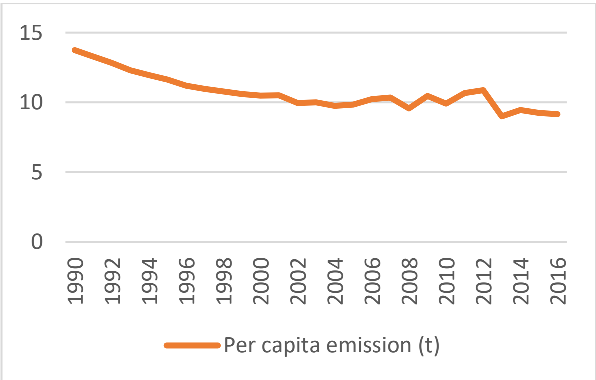


**Figure 3.2 - Per capita GHG emissions (1990 - 2016)**

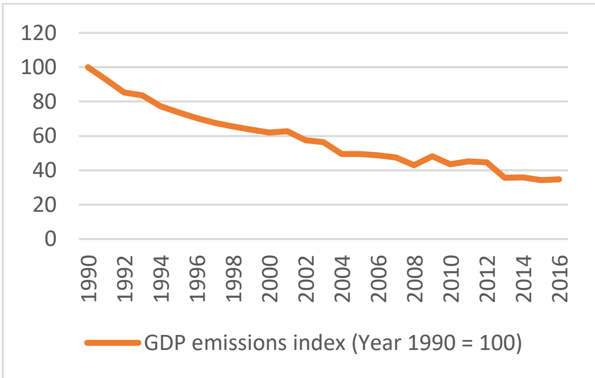


**Figure 3.3 - GDP emissions index (1990 - 2016)**

## 3.3. Trend of emissions by sector

The AFOLU sector remained the leading emitter throughout this period followed by Energy, for all years under review. Following the setting up of new industries, the IPPU sector took over as the third emitter in lieu of the Waste sector as from the year 2005. Emissions from the AFOLU sector regressed from 18,481 Gg $CO_2$-eq in 1990 to 16,902 in 2016, representing a decrease of 9% from the 1990 level. The share of GHG emissions from the AFOLU sector out of total national emissions regressed from 94% in 1990 to 80% in 2016.

Energy emissions increased from 1,117 Gg $CO_2$-eq (6.0%) of national emissions in 1990 to 3,791 Gg $CO_2$-eq (18%) in 2016 as depicted in Table 3.2. During the period 1990 to 2016, emissions more than tripled.

The contribution of the IPPU sector in total national emissions increased from 21 Gg $CO_2$-eq in 1990 to 482 Gg $CO_2$-eq in 2015 (Table 3.2) to regress to 401 Gg $CO_2$-eq in 2016 since lime production ceased. The very sharp increase in GHG emissions in the IPPU sector in 2011 is due to the commencement of the production of cement.

Waste emissions on the other hand increased steadily but slowly over this period. Emissions from the waste sector increased from the 1990 level of 73 Gg $CO_2$-eq to 167 Gg $CO_2$-eq in 2016, representing a 130% increase.

In 2016, Energy contributed 18% of emissions, IPPU 2%, AFOLU 79% and Waste 1%.

**Table 3.2 - National GHG emissions (Gg, $CO_2$-eq) by sector (1990 - 2016)**

| Year | Total emissions | Energy | IPPU | AFOLU | Waste |
|---|---|---|---|---|---|
| 1990 | 19,692 | 1,117 | 21 | 18,481 | 73 |
| 1991 | 19,775 | 1,200 | 21 | 18,478 | 76 |
| 1992 | 19,495 | 1,275 | 22 | 18,120 | 79 |
| 1993 | 19,072 | 1,373 | 23 | 17,595 | 81 |
| 1994 | 18,921 | 1,488 | 23 | 17,328 | 82 |
| 1995 | 18,791 | 1,497 | 30 | 17,183 | 81 |
| 1996 | 18,482 | 1,590 | 35 | 16,777 | 80 |
| 1997 | 18,490 | 1,641 | 41 | 16,726 | 82 |
| 1998 | 18,547 | 1,783 | 46 | 16,633 | 85 |
| 1999 | 18,609 | 1,918 | 51 | 16,551 | 89 |
| 2000 | 18,787 | 1,960 | 55 | 16,678 | 94 |
| 2001 | 19,222 | 2,142 | 58 | 16,927 | 95 |
| 2002 | 18,462 | 2,190 | 64 | 16,112 | 96 |
| 2003 | 18,834 | 2,482 | 70 | 16,176 | 106 |
| 2004 | 18,618 | 2,549 | 81 | 15,879 | 108 |
| 2005 | 19,030 | 2,699 | 123 | 16,095 | 114 |
| 2006 | 20,098 | 2,853 | 124 | 17,004 | 116 |
| 2007 | 20,596 | 2,938 | 129 | 17,415 | 113 |
| 2008 | 19,294 | 2,788 | 129 | 16,256 | 121 |
| 2009 | 21,423 | 2,873 | 132 | 18,289 | 129 |
| 2010 | 20,589 | 2,963 | 126 | 17,365 | 135 |
| 2011 | 22,581 | 2,832 | 281 | 19,326 | 142 |
| 2012 | 23,424 | 3,041 | 356 | 19,875 | 152 |
| 2013 | 19,750 | 2,900 | 406 | 16,291 | 153 |
| 2014 | 21,147 | 3,276 | 443 | 17,271 | 157 |
| 2015 | 21,089 | 3,587 | 482 | 16,856 | 165 |
| 2016 | 21,260 | 3,791 | 401 | 16,902 | 167 |

## 3.4. Trend in emissions of direct GHGs

The share of emissions by gas did not change during the period 1990 to 2016. The main contributor to the national GHG emissions remained $CO_2$ followed by $CH_4$ and $N_2O$. However, the share of $CO_2$ increased while those of $CH_4$ and $N_2O$ regressed over the time series. Halogenated gases crept in as from 1993 with a slight increase over the period under review. In 2016, the share of the GHG emissions was as follows: 64% $CO_2$, 22% $CH_4$, 13% $N_2O$ and 1% halogenated gases. The trend of the aggregated emissions and removals by gas is given in Table 3.3 and Figure 3.4.

**Table 3.3 - Aggregated emissions and removals (Gg) by gas (1990 - 2016)**

| Year | Total emissions ($CO_2$-eq) | Removals ($CO_2$) | $CO_2$ | $CH_4$ ($CO_2$-eq) | $N_2O$ ($CO_2$-eq) | Halogenated gases ($CO_2$-eq) |
|---|---|---|---|---|---|---|
| 1990 | 19,692 | -90,021 | 9,801 | 6,633 | 3,258 | - |
| 1991 | 19,775 | -91,794 | 9,882 | 6,625 | 3,268 | - |
| 1992 | 19,495 | -93,706 | 9,956 | 6,390 | 3,150 | - |
| 1993 | 19,072 | -95,488 | 10,053 | 6,043 | 2,975 | 0.2 |
| 1994 | 18,921 | -97,288 | 10,166 | 5,862 | 2,893 | 0.3 |
| 1995 | 18,791 | -99,105 | 10,174 | 5,752 | 2,859 | 6 |
| 1996 | 18,482 | -100,940 | 10,266 | 5,482 | 2,723 | 11 |
| 1997 | 18,490 | -102,793 | 10,316 | 5,439 | 2,719 | 16 |
| 1998 | 18,547 | -104,845 | 10,456 | 5,376 | 2,695 | 20 |
| 1999 | 18,609 | -106,748 | 10,589 | 5,319 | 2,677 | 24 |
| 2000 | 18,787 | -108,809 | 10,629 | 5,392 | 2,737 | 28 |
| 2001 | 19,222 | -109,091 | 11,021 | 5,417 | 2,752 | 32 |
| 2002 | 18,462 | -113,365 | 11,109 | 4,820 | 2,497 | 36 |
| 2003 | 18,834 | -113,824 | 11,356 | 4,897 | 2,541 | 40 |
| 2004 | 18,618 | -115,598 | 11,425 | 4,689 | 2,457 | 47 |
| 2005 | 19,030 | -113,368 | 11,570 | 4,856 | 2,515 | 89 |
| 2006 | 20,098 | -109,749 | 11,720 | 5,482 | 2,805 | 91 |
| 2007 | 20,596 | -106,971 | 11,805 | 5,741 | 2,957 | 93 |
| 2008 | 19,294 | -115,558 | 11,660 | 4,970 | 2,578 | 86 |
| 2009 | 21,423 | -103,774 | 11,741 | 6,391 | 3,206 | 86 |
| 2010 | 20,589 | -107,920 | 11,825 | 5,760 | 2,921 | 85 |
| 2011 | 22,581 | -106,002 | 12,673 | 6,503 | 3,315 | 90 |
| 2012 | 23,424 | -105,021 | 12,952 | 6,871 | 3,509 | 91 |
| 2013 | 19,750 | -122,901 | 12,857 | 4,421 | 2,377 | 95 |
| 2014 | 21,147 | -120,007 | 13,258 | 5,105 | 2,683 | 101 |
| 2015 | 21,089 | -122,078 | 13,587 | 4,804 | 2,585 | 113 |
| 2016 | 21,260 | -126,688 | 13,700 | 4,775 | 2,665 | 120 |

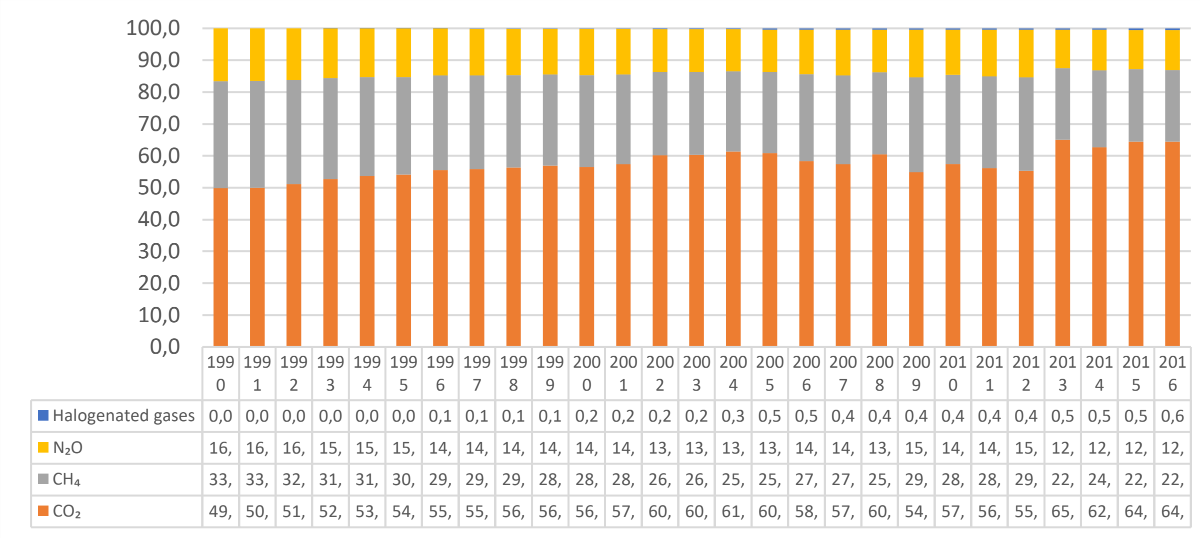


**Figure 3.4 - Share of aggregated emissions (Gg $CO_2$-eq) by gas (1990 - 2016)**

### 3.4.1. Carbon dioxide ($CO_2$)

$CO_2$ emissions increased by 40% from 9,801 Gg in 1990 to 13,700 Gg in 2016 (Table 3.34). In the same year, the sector that emitted the highest amount of $CO_2$ was AFOLU with 9,770 Gg followed by Energy with 3,649 Gg (Table 3.4).

**Table 3.4 - $CO_2$ emissions (Gg) by source category (1990 - 2016)**

| Year | Total emissions | Total net removals | Energy | IPPU | AFOLU - emissions | AFOLU - removals | Waste |
|---|---|---|---|---|---|---|---|
| 1990 | 9,801 | -80,220 | 1,044 | 20 | 8,736 | -90,021 | 0.8 |
| 1991 | 9,882 | -81,912 | 1,125 | 20 | 8,736 | -91,794 | 0.9 |
| 1992 | 9,956 | -83,750 | 1,198 | 21 | 8,736 | -93,706 | 0.9 |
| 1993 | 10,053 | -85,435 | 1,295 | 22 | 8,736 | -95,488 | 0.9 |
| 1994 | 10,166 | -87,122 | 1,407 | 22 | 8,736 | -97,288 | 1.0 |
| 1995 | 10,174 | -88,931 | 1,415 | 23 | 8,736 | -99,105 | 1.0 |
| 1996 | 10,266 | -90,675 | 1,506 | 23 | 8,736 | -100,940 | 1.0 |
| 1997 | 10,316 | -92,477 | 1,555 | 24 | 8,736 | -102,793 | 1.1 |
| 1998 | 10,456 | -94,389 | 1,694 | 24 | 8,736 | -104,845 | 1.1 |
| 1999 | 10,589 | -96,159 | 1,827 | 25 | 8,735 | -106,748 | 1.2 |
| 2000 | 10,629 | -98,179 | 1,868 | 25 | 8,736 | -108,809 | 1.2 |
| 2001 | 11,021 | -98,070 | 2,046 | 25 | 8,949 | -109,091 | 1.3 |
| 2002 | 11,109 | -102,256 | 2,093 | 27 | 8,988 | -113,365 | 1.3 |
| 2003 | 11,356 | -102,468 | 2,379 | 29 | 8,947 | -113,824 | 1.4 |
| 2004 | 11,425 | -104,174 | 2,444 | 32 | 8,947 | -115,598 | 1.4 |
| 2005 | 11,570 | -101,798 | 2,590 | 32 | 8,947 | -113,368 | 1.5 |
| 2006 | 11,720 | -98,029 | 2,740 | 32 | 8,947 | -109,749 | 1.6 |
| 2007 | 11,805 | -95,166 | 2,822 | 35 | 8,947 | -106,971 | 1.7 |
| 2008 | 11,660 | -103,898 | 2,671 | 41 | 8,946 | -115,558 | 1.7 |
| 2009 | 11,741 | -92,033 | 2,748 | 44 | 8,947 | -103,774 | 1.8 |
| 2010 | 11,825 | -96,095 | 2,837 | 40 | 8,947 | -107,920 | 1.9 |
| 2011 | 12,673 | -93,329 | 2,713 | 189 | 9,769 | -106,002 | 2.1 |

| Year | Total emissions | Total net removals | Energy | IPPU | AFOLU - emissions | AFOLU - removals | Waste |
|---|---|---|---|---|---|---|---|
| 2012 | 12,952 | -92,069 | 2,918 | 262 | 9,769 | -105,021 | 2.3 |
| 2013 | 12,857 | -110,044 | 2,776 | 309 | 9,769 | -122,901 | 2.3 |
| 2014 | 13,258 | -106,748 | 3,146 | 340 | 9,769 | -120,007 | 2.4 |
| 2015 | 13,587 | -108,491 | 3,450 | 366 | 9,769 | -122,078 | 2.4 |
| 2016 | 13,700 | -112,988 | 3,649 | 279 | 9,770 | -126,688 | 2.4 |

### 3.4.2. Methane ($CH_4$)

$CH_4$ contributed 4,775 Gg $CO_2$-eq of the total emissions of 2016. $CH_4$ emissions decreased by 1,858 Gg $CO_2$-eq from the 1990 level of 6,633 Gg $CO_2$-eq to 4,775 in 2016 (Table 3.5). AFOLU contributed between 96% of these emissions in 2016 followed by the Waste sector with 3%.

**Table 3.5 - $CH_4$ emissions (Gg) by source category (1990 - 2016)**

| Year | Total (Gg $CO_2$-eq) | Total | Energy | AFOLU - emissions | Waste |
|---|---|---|---|---|---|
| 1990 | 6,633 | 316 | 2.2 | 311 | 2.4 |
| 1991 | 6,625 | 315 | 2.3 | 311 | 2.5 |
| 1992 | 6,390 | 304 | 2.3 | 299 | 2.6 |
| 1993 | 6,043 | 288 | 2.3 | 283 | 2.7 |
| 1994 | 5,862 | 279 | 2.4 | 274 | 2.8 |
| 1995 | 5,752 | 274 | 2.4 | 269 | 2.7 |
| 1996 | 5,482 | 261 | 2.4 | 256 | 2.6 |
| 1997 | 5,439 | 259 | 2.4 | 254 | 2.7 |
| 1998 | 5,376 | 256 | 2.5 | 251 | 2.8 |
| 1999 | 5,319 | 253 | 2.5 | 248 | 3.0 |
| 2000 | 5,392 | 257 | 2.5 | 251 | 3.2 |
| 2001 | 5,417 | 258 | 2.6 | 252 | 3.3 |
| 2002 | 4,820 | 230 | 2.6 | 224 | 3.3 |
| 2003 | 4,897 | 233 | 2.7 | 227 | 3.8 |
| 2004 | 4,689 | 223 | 2.7 | 217 | 3.8 |
| 2005 | 4,856 | 231 | 2.8 | 224 | 4.1 |
| 2006 | 5,482 | 261 | 2.8 | 254 | 4.2 |
| 2007 | 5,741 | 273 | 2.9 | 267 | 4.0 |
| 2008 | 4,970 | 237 | 2.9 | 229 | 4.4 |
| 2009 | 6,391 | 304 | 3.0 | 297 | 4.7 |
| 2010 | 5,760 | 274 | 3.1 | 266 | 5.0 |
| 2011 | 6,503 | 310 | 3.0 | 301 | 5.3 |
| 2012 | 6,871 | 327 | 3.0 | 318 | 5.8 |
| 2013 | 4,421 | 211 | 3.0 | 202 | 5.9 |
| 2014 | 5,105 | 243 | 3.0 | 234 | 6.1 |
| 2015 | 4,804 | 229 | 3.1 | 219 | 6.4 |
| 2016 | 4,775 | 227 | 3.1 | 218 | 6.5 |

### 3.4.3. Nitrous Oxide ($N_2O$)

$N_2O$ emissions stood at 2,665 Gg $CO_2$-eq in 2016. Emissions regressed by 593 Gg $CO_2$-eq from 3,258 Gg $CO_2$-eq in the year 1990 to 2,665 Gg $CO_2$-eq (Table 3.6) in 2016. The AFOLU sector was the highest emitter of $N_2O$ with some 96%.

**Table 3.6 - $N_2O$ emissions (Gg) by source category (1990 - 2016)**

| Year | Total emissions ($CO_2$-eq) | Total | Energy | IPPU | AFOLU - emissions | Waste |
|---|---|---|---|---|---|---|
| 1990 | 3,258 | 10.5 | 0.08 | 0.002 | 10.35 | 0.07 |
| 1991 | 3,268 | 10.54 | 0.09 | 0.003 | 10.38 | 0.07 |
| 1992 | 3,150 | 10.16 | 0.09 | 0.003 | 9.99 | 0.07 |
| 1993 | 2,975 | 9.60 | 0.10 | 0.003 | 9.43 | 0.07 |
| 1994 | 2,893 | 9.33 | 0.10 | 0.003 | 9.15 | 0.08 |
| 1995 | 2,859 | 9.22 | 0.10 | 0.003 | 9.04 | 0.08 |
| 1996 | 2,723 | 8.78 | 0.11 | 0.004 | 8.59 | 0.08 |
| 1997 | 2,719 | 8.77 | 0.11 | 0.004 | 8.58 | 0.08 |
| 1998 | 2,695 | 8.69 | 0.12 | 0.004 | 8.49 | 0.08 |
| 1999 | 2,677 | 8.63 | 0.12 | 0.004 | 8.43 | 0.08 |
| 2000 | 2,737 | 8.83 | 0.13 | 0.004 | 8.62 | 0.08 |
| 2001 | 2,752 | 8.88 | 0.14 | 0.005 | 8.66 | 0.08 |
| 2002 | 2,497 | 8.06 | 0.14 | 0.005 | 7.83 | 0.08 |
| 2003 | 2,541 | 8.20 | 0.15 | 0.005 | 7.96 | 0.08 |
| 2004 | 2,457 | 7.93 | 0.16 | 0.005 | 7.68 | 0.08 |
| 2005 | 2,515 | 8.11 | 0.16 | 0.005 | 7.86 | 0.09 |
| 2006 | 2,805 | 9.05 | 0.17 | 0.006 | 8.78 | 0.09 |
| 2007 | 2,957 | 9.54 | 0.18 | 0.006 | 9.26 | 0.09 |
| 2008 | 2,578 | 8.32 | 0.18 | 0.006 | 8.04 | 0.09 |
| 2009 | 3,206 | 10.34 | 0.20 | 0.006 | 10.05 | 0.09 |
| 2010 | 2,921 | 9.42 | 0.20 | 0.007 | 9.13 | 0.09 |
| 2011 | 3,315 | 10.69 | 0.18 | 0.007 | 10.41 | 0.09 |
| 2012 | 3,509 | 11.32 | 0.19 | 0.007 | 11.03 | 0.09 |
| 2013 | 2,377 | 7.67 | 0.20 | 0.007 | 7.37 | 0.09 |
| 2014 | 2,683 | 8.65 | 0.21 | 0.008 | 8.35 | 0.09 |
| 2015 | 2,585 | 8.34 | 0.23 | 0.008 | 8.01 | 0.09 |
| 2016 | 2,665 | 8.60 | 0.24 | 0.008 | 8.26 | 0.09 |

## 3.5. Trends for indirect GHGs and $SO_2$

Emissions of indirect GHGs (CO, $NO_x$ and NMVOC) and $SO_2$ have also been estimated and reported in this inventory. Indirect GHGs have not been included in national total emissions. Emissions of these gases for the period 1990 to 2016 are given in Table 3.7.

Emissions of $NO_x$ decreased from 52 Gg in the year 1990 to 35.1 Gg in 2016. CO emissions also regressed, from 2,677 Gg in 1990 to 446 Gg in 2016. Emissions of NMVOCs increased from 17 Gg in 1990 to 28 Gg in 2016 whilst emissions of $SO_2$ varied between 1.9 Gg and 4.3 Gg during the same period.

Table 3.7 - Emissions (Gg) of indirect GHGs and $SO_2$ (1990 - 2016)

| Year | $NO_x$ | CO | NMVOC | $SO_2$ |
|---|---|---|---|---|
| 1990 | 52.0 | 2,676.9 | 16.6 | 1.9 |
| 1991 | 51.1 | 2,556.7 | 17.4 | 2.1 |
| 1992 | 49.9 | 2,436.1 | 17.4 | 2.2 |
| 1993 | 49.3 | 2,322.6 | 17.1 | 2.4 |
| 1994 | 48.9 | 2,208.2 | 17.4 | 2.7 |
| 1995 | 45.6 | 2,092.8 | 17.5 | 2.2 |
| 1996 | 44.3 | 1,976.6 | 17.7 | 2.2 |
| 1997 | 42.0 | 1,859.2 | 18.3 | 2.0 |
| 1998 | 41.9 | 1,741.1 | 19.1 | 2.3 |
| 1999 | 41.7 | 1,622.0 | 19.9 | 2.6 |
| 2000 | 39.6 | 1,475.4 | 21.3 | 2.3 |
| 2001 | 41.2 | 1,488.7 | 21.2 | 2.5 |
| 2002 | 37.6 | 1,143.0 | 20.9 | 2.8 |
| 2003 | 39.4 | 1,151.0 | 21.7 | 3.1 |
| 2004 | 37.5 | 1,035.4 | 22.1 | 3.6 |
| 2005 | 41.7 | 1,278.1 | 22.0 | 3.8 |
| 2006 | 46.2 | 1,629.9 | 23.0 | 4.3 |
| 2007 | 49.9 | 1,915.8 | 23.1 | 4.1 |
| 2008 | 37.9 | 1,212.3 | 23.1 | 4.3 |
| 2009 | 56.0 | 2,275.6 | 23.6 | 3.8 |
| 2010 | 52.2 | 1,958.5 | 23.7 | 3.1 |
| 2011 | 53.5 | 2,089.6 | 24.8 | 3.1 |
| 2012 | 57.2 | 2,178.9 | 25.9 | 3.9 |
| 2013 | 31.7 | 669.8 | 24.5 | 2.6 |
| 2014 | 39.2 | 951.5 | 26.6 | 2.9 |
| 2015 | 39.5 | 799.9 | 26.5 | 3.0 |
| 2016 | 35.1 | 445.9 | 28.3 | 3.6 |

### 3.5.1. Oxides of nitrogen ($NO_x$)

Emissions of $NO_x$ decreased by 33% over the inventory period from 52.0 Gg in the year 1990 to 35.1 Gg in 2016 (Table 3.8). The two main sources of $NO_x$ emissions were the Energy and AFOLU sectors. The Energy sector witnessed an increase from 10.4 Gg to 29.1 Gg while the AFOLU sector contribution regressed from 41 Gg to 5 Gg from 1990 to 2016. Waste contributed the remainder, less than 1 Gg for all years.

Table 3.8 - $NO_x$ emissions (Gg) by source category (1990 - 2016)

| Year | Total emissions | Energy | AFOLU | Waste |
|---|---|---|---|---|
| 1990 | 52.0 | 10.4 | 41.4 | 0.2 |
| 1991 | 51.1 | 11.5 | 39.5 | 0.2 |
| 1992 | 49.9 | 12.2 | 37.5 | 0.2 |
| 1993 | 49.3 | 13.4 | 35.7 | 0.2 |
| 1994 | 48.9 | 14.9 | 33.8 | 0.2 |
| 1995 | 45.6 | 13.4 | 32.0 | 0.2 |

| Year | Total emissions | Energy | AFOLU | Waste |
|---|---|---|---|---|
| 1996 | 44.3 | 14.0 | 30.1 | 0.2 |
| 1997 | 42.0 | 13.5 | 28.2 | 0.2 |
| 1998 | 41.9 | 15.4 | 26.3 | 0.2 |
| 1999 | 41.7 | 17.0 | 24.4 | 0.2 |
| 2000 | 39.6 | 17.3 | 22.1 | 0.2 |
| 2001 | 41.2 | 18.7 | 22.2 | 0.3 |
| 2002 | 37.6 | 20.5 | 16.8 | 0.3 |
| 2003 | 39.4 | 22.3 | 16.8 | 0.3 |
| 2004 | 37.5 | 22.3 | 14.9 | 0.3 |
| 2005 | 41.7 | 22.7 | 18.7 | 0.3 |
| 2006 | 46.2 | 21.7 | 24.1 | 0.3 |
| 2007 | 49.9 | 21.1 | 28.5 | 0.3 |
| 2008 | 37.9 | 19.9 | 17.6 | 0.4 |
| 2009 | 56.0 | 21.6 | 34.1 | 0.4 |
| 2010 | 52.2 | 22.8 | 29.1 | 0.4 |
| 2011 | 53.5 | 21.9 | 31.2 | 0.4 |
| 2012 | 57.2 | 24.2 | 32.5 | 0.5 |
| 2013 | 31.7 | 22.2 | 9.1 | 0.5 |
| 2014 | 39.2 | 25.3 | 13.3 | 0.5 |
| 2015 | 39.5 | 28.0 | 11.0 | 0.5 |
| 2016 | 35.1 | 29.1 | 5.4 | 0.5 |

### 3.5.2. Carbon monoxide (CO)

The major contributor of CO was the AFOLU sector with between 78% and 98% of national emission followed by the Energy sector with between 2% to 4% (Table 3.9). National CO emissions decreased from 2,677 Gg in the year 1990 to 446 Gg in 2016. The AFOLU sector contributed 349 Gg of total CO emissions compared to 88 Gg by the Energy sector and 9 Gg by the Waste sector in 2016.

**Table 3.9 - CO emissions (Gg) by source category (1990 - 2016)**

| Year | Total emissions | Energy | %Energy | AFOLU | %AFOLU | Waste | %Waste |
|---|---|---|---|---|---|---|---|
| 1990 | 2,676.9 | 46.6 | 1.7% | 2,627.3 | 98.1% | 3.0 | 0.1% |
| 1991 | 2,556.7 | 48.2 | 1.9% | 2,505.4 | 98.0% | 3.1 | 0.1% |
| 1992 | 2,436.1 | 49.5 | 2.0% | 2,383.3 | 97.8% | 3.2 | 0.1% |
| 1993 | 2,322.6 | 50.9 | 2.2% | 2,268.3 | 97.7% | 3.3 | 0.1% |
| 1994 | 2,208.2 | 52.4 | 2.4% | 2,152.3 | 97.5% | 3.5 | 0.2% |
| 1995 | 2,092.8 | 54.0 | 2.6% | 2,035.2 | 97.3% | 3.6 | 0.2% |
| 1996 | 1,976.6 | 55.7 | 2.8% | 1,917.2 | 97.0% | 3.7 | 0.2% |
| 1997 | 1,859.2 | 57.3 | 3.1% | 1,798.1 | 96.7% | 3.9 | 0.2% |
| 1998 | 1,741.1 | 59.1 | 3.4% | 1,678.0 | 96.4% | 4.0 | 0.2% |
| 1999 | 1,622.0 | 60.9 | 3.8% | 1,556.9 | 96.0% | 4.2 | 0.3% |
| 2000 | 1,475.4 | 62.8 | 4.3% | 1,408.3 | 95.5% | 4.3 | 0.3% |
| 2001 | 1,488.7 | 65.5 | 4.4% | 1,418.8 | 95.3% | 4.5 | 0.3% |
| 2002 | 1,143.0 | 65.7 | 5.7% | 1,072.6 | 93.8% | 4.7 | 0.4% |
| 2003 | 1,151.0 | 70.4 | 6.1% | 1,075.7 | 93.5% | 5.0 | 0.4% |

| Year | Total emissions | Energy | %Energy | AFOLU | %AFOLU | Waste | %Waste |
|---|---|---|---|---|---|---|---|
| 2004 | 1,035.4 | 73.5 | 7.1% | 956.7 | 92.4% | 5.2 | 0.5% |
| 2005 | 1,278.1 | 75.9 | 5.9% | 1,196.7 | 93.6% | 5.4 | 0.4% |
| 2006 | 1,629.9 | 78.5 | 4.8% | 1,545.7 | 94.8% | 5.7 | 0.4% |
| 2007 | 1,915.8 | 80.6 | 4.2% | 1,829.3 | 95.5% | 6.0 | 0.3% |
| 2008 | 1,212.3 | 76.5 | 6.3% | 1,129.5 | 93.2% | 6.3 | 0.5% |
| 2009 | 2,275.6 | 79.3 | 3.5% | 2,189.8 | 96.2% | 6.6 | 0.3% |
| 2010 | 1,958.5 | 83.6 | 4.3% | 1,868.1 | 95.4% | 6.9 | 0.4% |
| 2011 | 2,089.6 | 79.0 | 3.8% | 2,003.0 | 95.9% | 7.5 | 0.4% |
| 2012 | 2,178.9 | 79.4 | 3.6% | 2,091.2 | 96.0% | 8.2 | 0.4% |
| 2013 | 669.8 | 79.1 | 11.8% | 582.4 | 86.9% | 8.4 | 1.2% |
| 2014 | 951.5 | 85.0 | 8.9% | 858.0 | 90.2% | 8.5 | 0.9% |
| 2015 | 799.9 | 86.4 | 10.8% | 704.9 | 88.1% | 8.6 | 1.1% |
| 2016 | 445.9 | 87.9 | 19.7% | 349.3 | 78.3% | 8.7 | 2.0% |

### 3.5.3. Non-Methane Volatile Organic Compound (NMVOCs)

In 2016, NMVOCs emissions stood at 28.3 Gg compared to 17 Gg in the year 1990. The two main emission sources were the Energy and AFOLU sectors (Table 3.10). NMVOC emissions increased throughout the inventory period for these two sectors with slight variations between years. Emissions from the Waste sector increased from 0.1 Gg to 0.6 Gg during the inventory period.

Table 3.10 - NMVOC emissions (Gg) by source category (1990 - 2016)

| Year | Total emissions | Energy | IPPU | AFOLU | Waste |
|---|---|---|---|---|---|
| 1990 | 16.6 | 6.5 | 0.5 | 9.5 | 0.1 |
| 1991 | 17.4 | 6.7 | 0.5 | 10.0 | 0.1 |
| 1992 | 17.4 | 6.9 | 0.6 | 9.8 | 0.1 |
| 1993 | 17.1 | 7.1 | 0.6 | 9.2 | 0.1 |
| 1994 | 17.4 | 7.4 | 0.7 | 9.2 | 0.2 |
| 1995 | 17.5 | 7.5 | 0.7 | 9.1 | 0.2 |
| 1996 | 17.7 | 7.7 | 0.8 | 9.0 | 0.2 |
| 1997 | 18.3 | 7.9 | 0.9 | 9.3 | 0.2 |
| 1998 | 19.1 | 8.2 | 1.1 | 9.7 | 0.2 |
| 1999 | 19.9 | 8.4 | 1.2 | 10.0 | 0.2 |
| 2000 | 21.3 | 8.7 | 1.3 | 11.0 | 0.2 |
| 2001 | 21.2 | 8.6 | 1.5 | 10.9 | 0.2 |
| 2002 | 20.9 | 8.7 | 1.4 | 10.5 | 0.2 |
| 2003 | 21.7 | 9.2 | 1.6 | 10.6 | 0.3 |
| 2004 | 22.1 | 9.6 | 1.6 | 10.6 | 0.3 |
| 2005 | 22.0 | 9.9 | 1.7 | 10.1 | 0.3 |
| 2006 | 23.0 | 10.2 | 1.7 | 10.7 | 0.3 |
| 2007 | 23.1 | 10.5 | 1.8 | 10.5 | 0.3 |
| 2008 | 23.1 | 10.0 | 1.9 | 10.8 | 0.4 |
| 2009 | 23.6 | 10.4 | 2.1 | 10.7 | 0.4 |
| 2010 | 23.7 | 10.9 | 2.1 | 10.3 | 0.4 |
| 2011 | 24.8 | 10.5 | 2.2 | 11.7 | 0.5 |

| Year | Total emissions | Energy | IPPU | AFOLU | Waste |
|---|---|---|---|---|---|
| 2012 | 25.9 | 10.7 | 2.3 | 12.5 | 0.5 |
| 2013 | 24.5 | 10.4 | 2.3 | 11.3 | 0.5 |
| 2014 | 26.6 | 11.1 | 2.3 | 12.6 | 0.5 |
| 2015 | 26.5 | 11.3 | 2.4 | 12.2 | 0.6 |
| 2016 | 28.3 | 11.5 | 2.6 | 13.5 | 0.6 |

### 3.5.4. Sulphur dioxide ($SO_2$)

The energy sector remained nearly the sole emitter of $SO_2$ (Table 3.11) during the full inventory period. Emissions fluctuated from 1.9 Gg to 4.3 Gg during the inventory period 1990 to 2016. The Waste sector emitted an insignificant amount varying from 0.01 to 0.02 Gg.

**Table 3.11 - $SO_2$ emissions (Gg) by source category (1990 - 2016)**

| Year | Total emissions | Energy | Waste |
|---|---|---|---|
| 1990 | 1.88 | 1.88 | 0.01 |
| 1991 | 2.09 | 2.09 | 0.01 |
| 1992 | 2.22 | 2.21 | 0.01 |
| 1993 | 2.43 | 2.43 | 0.01 |
| 1994 | 2.72 | 2.71 | 0.01 |
| 1995 | 2.21 | 2.20 | 0.01 |
| 1996 | 2.24 | 2.23 | 0.01 |
| 1997 | 1.99 | 1.98 | 0.01 |
| 1998 | 2.33 | 2.32 | 0.01 |
| 1999 | 2.62 | 2.61 | 0.01 |
| 2000 | 2.27 | 2.26 | 0.01 |
| 2001 | 2.47 | 2.46 | 0.01 |
| 2002 | 2.82 | 2.81 | 0.01 |
| 2003 | 3.08 | 3.07 | 0.01 |
| 2004 | 3.60 | 3.59 | 0.01 |
| 2005 | 3.81 | 3.80 | 0.01 |
| 2006 | 4.28 | 4.26 | 0.01 |
| 2007 | 4.09 | 4.08 | 0.01 |
| 2008 | 4.26 | 4.25 | 0.01 |
| 2009 | 3.85 | 3.83 | 0.01 |
| 2010 | 3.09 | 3.07 | 0.01 |
| 2011 | 3.14 | 3.13 | 0.01 |
| 2012 | 3.86 | 3.85 | 0.02 |
| 2013 | 2.63 | 2.62 | 0.02 |
| 2014 | 2.86 | 2.84 | 0.02 |
| 2015 | 3.01 | 2.99 | 0.02 |
| 2016 | 3.61 | 3.59 | 0.02 |

### 3.5.5. Halogenated non- Ozone Depleting Substances (ODS) emissions (1990 - 2016)

Halogenated non-ODS emissions were compiled as from 1993 only as this was the year these products came into use for the first time. Emissions increased from 0.2 Gg in 1990 to 119.6 Gg in 2016.

Table 3.12 - Halogenated non-ODS emissions (Gg $CO_2$-eq) by source category (1990 - 2016)

| Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Emissions (Gg) | - | - | - | 0.2 | 0.3 | 5.9 | 11.0 | 15.8 | 20.2 | 24.4 | 28.4 | 32.2 | 35.7 | 40.3 | 47.4 |

| Year | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Emissions (Gg) | 89.4 | 91.0 | 92.6 | 85.8 | 85.7 | 84.6 | 89.7 | 91.2 | 94.7 | 100.7 | 113.2 | 119.6 |

### Table 3.12 - Short Summary Table (Inventory Year 2016)

| Categories | Emissions (Gg) | | | Emissions CO2 Equivalents (Gg) | | | | Emissions (Gg) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Net CO2 (1)(2) | CH4 | N2O | HFCs | PFCs | SF6 | Other halogenated gases with CO2 equivalent conversion factors (3) | Other halogenated gases without CO2 equivalent conversion factors (4) | NOx | CO | NMVOCs | SO2 |
| Total National Emissions and Removals | -112987.964 | 227.401 | 8.596 | 119.551 | NE | NE | NE | NE | 35.069 | 445.903 | 28.290 | 3.605 |
| 1 - Energy | 3649.200 | 3.146 | 0.244 | NA | NA | NA | NA | NA | 29.146 | 87.920 | 11.514 | 3.588 |
| 1.A - Fuel Combustion Activities | 3649.200 | 3.146 | 0.244 | NA | NA | NA | NA | NA | 29.146 | 87.920 | 11.514 | 3.588 |
| 1.B - Fugitive emissions from fuels | NO | NO | NO | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 1.C - Carbon dioxide Transport and Storage | NO | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 2 - Industrial Processes and Product Use | 278.846 | NO | 0.008 | 119.551 | NE | NE | NE | NE | NO | NO | 2.644 | NO |
| 2.A - Mineral Industry | 262.624 | NO | NO | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.B - Chemical Industry | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 2.C - Metal Industry | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 2.D - Non-Energy Products from Fuels and Solvent Use | 16.221 | NO | NO | NA | NA | NA | NA | NA | NO | NO | 1.367 | NO |
| 2.E - Electronics Industry | NO | NO | NO | NO | NO | NO | NO | NO | NA | NA | NA | NA |
| 2.F - Product Uses as Substitutes for Ozone Depleting Substances | NA | NA | NA | 119.551 | NE | NA | NA | NA | NA | NA | NA | NA |
| 2.G - Other Product Manufacture and Use | NO | NO | 0.008 | NO | NE | NE | NO | NE | NA | NA | NA | NA |
| 2.H - Other | 0.000 | 0.000 | 0.000 | NA | NA | NA | NA | NA | 0.000 | 0.000 | 1.278 | 0.000 |
| 3 - Agriculture, Forestry, and Other Land Use | -116918.432 | 217.723 | 8.257 | NA | NA | NA | NA | NA | 5.426 | 349.270 | 13.544 | NO |
| 3.A - Livestock | NA | 194.921 | 0.511 | NA | NA | NA | NA | NA | NA | NA | 13.544 | NA |
| 3.B - Land | -116829.341 | 0.000 | 0.000 | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 3.C - Aggregate sources and non-CO2 emissions sources on land | 1.256 | 22.801 | 7.746 | NA | NA | NA | NA | NA | 5.426 | 349.270 | NA | NA |
| 3.D - Other | -90.347 | NO | NO | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 4 - Waste | 2.422 | 6.533 | 0.087 | NA | NA | NA | NA | NA | 0.496 | 8.714 | 0.588 | 0.017 |

| Categories | Emissions (Gg) | | | Emissions CO2 Equivalents (Gg) | | | | | Emissions (Gg) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Net CO2 (1)(2) | CH4 | N2O | HFCs | PFCs | SF6 | Other halogenated gases with CO2 equivalent conversion factors (3) | Other halogenated gases without CO2 equivalent conversion factors (4) | NOx | CO | NMVOCs | SO2 |
| 4.A - Solid Waste Disposal | NA | 4.239 | NO | NA | NA | NA | NA | NA | NO | NO | 0.396 | NA |
| 4.B - Biological Treatment of Solid Waste | NA | NO | NO | NA | NA | NA | NA | NA | NO | NO | NO | NA |
| 4.C - Incineration and Open Burning of Waste | 2.422 | 1.014 | 0.013 | NA | NA | NA | NA | NA | 0.496 | 8.713 | 0.192 | 0.017 |
| 4.D - Wastewater Treatment and Discharge | NA | 1.280 | 0.074 | NA | NA | NA | NA | NA | NO | NO | 0.000 | NA |
| 4.E - Other (please specify) | NO | NO | NO | NA | NA | NA | NA | NA | NO | NO | NO | NA |
| 5 - Other | NO | NO | NE | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 5.A - Indirect N2O emissions from the atmospheric deposition of nitrogen in NOx and NH3 | NA | NA | NE | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 5.B - Other (please specify) | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Memo Items (5) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| International Bunkers | 263.112 | 0.015 | 0.007 | NA | NA | NA | NA | NA | 4.267 | 0.789 | 0.274 | 1.015 |
| 1.A.3.a.i - International Aviation (International Bunkers) | 108.698 | 0.001 | 0.003 | NA | NA | NA | NA | NA | 0.441 | 0.038 | 0.017 | 0.035 |
| 1.A.3.d.i - International water-borne navigation (International bunkers) | 154.414 | 0.014 | 0.004 | NA | NA | NA | NA | NA | 3.825 | 0.752 | 0.257 | 0.981 |
| 1.A.5.c - Multilateral Operations | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |

## Table 3.13 - Long Summary Table (Inventory Year 2016)

| Categories | Emissions (Gg) | | | Emissions CO2 Equivalents (Gg) | | | | Emissions (Gg) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Net $CO_2$ (1)(2) | CH4 | N2O | HFCs | PFCs | SF6 | Other halogenated gases with CO2 equivalent conversion factors (3) | Other halogenated gases without CO2 equivalent conversion factors (4) | NOx | CO | NMVOCs | SO2 |
| Total National Emissions and Removals | -112987.964 | 227.401 | 8.596 | 119.551 | NE | NE | NE | NE | 35.069 | 445.903 | 28.290 | 3.605 |
| 1 - Energy | 3649.200 | 3.146 | 0.244 | NA | NA | NA | NA | NA | 29.146 | 87.920 | 11.514 | 3.588 |
| 1.A - Fuel Combustion Activities | 3649.200 | 3.146 | 0.244 | NA | NA | NA | NA | NA | 29.146 | 87.920 | 11.514 | 3.588 |
| 1.A.1 - Energy Industries | 86.867 | 0.321 | 0.044 | NA | NA | NA | NA | NA | 1.055 | 0.968 | 0.079 | 0.866 |
| 1.A.2 - Manufacturing Industries and Construction | 192.505 | 0.083 | 0.005 | NA | NA | NA | NA | NA | 0.736 | 1.435 | 0.359 | 0.923 |
| 1.A.3 - Transport | 2852.747 | 0.633 | 0.158 | NA | NA | NA | NA | NA | 18.988 | 54.242 | 5.812 | 0.027 |
| 1.A.4 - Other Sectors | 379.730 | 2.101 | 0.030 | NA | NA | NA | NA | NA | 6.941 | 30.839 | 5.173 | 1.771 |
| 1.A.5 - Non-Specified | 137.351 | 0.008 | 0.007 | NA | NA | NA | NA | NA | 1.426 | 0.435 | 0.091 | 0.001 |
| 1.B - Fugitive emissions from fuels | NO | NO | NO | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 1.B.1 - Solid Fuels | NO | NO | NA | NA | NA | NA | NA | NA | NA | NA | NA | NO |
| 1.B.2 - Oil and Natural Gas | NO | NO | NO | NA | NA | NA | NA | NA | NO | NO | NO | NA |
| 1.B.3 - Other emissions from Energy Production | NO | NO | NO | NA | NA | NA | NA | NA | NO | NO | NO | NA |
| 1.C - Carbon dioxide Transport and Storage | NO | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1.C.1 - Transport of CO2 | NO | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1.C.2 - Injection and Storage | NO | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1.C.3 - Other | NO | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 2 - Industrial Processes and Product Use | 278.846 | NO | 0.008 | 119.551 | NE | NE | NE | NE | NO | NO | 2.644 | NO |
| 2.A - Mineral Industry | 262.624 | NO | NO | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.A.1 - Cement production | 262.624 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 2.A.2 - Lime production | NO | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 2.A.3 - Glass Production | NO | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |

| Categories | Emissions (Gg) | | | Emissions CO2 Equivalents (Gg) | | | | Emissions (Gg) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Net $CO_2$ (1)(2) | CH4 | N2O | HFCs | PFCs | SF6 | Other halogenated gases with CO2 equivalent conversion factors (3) | Other halogenated gases without CO2 equivalent conversion factors (4) | NOx | CO | NMVOCs | SO2 |
| 2.A.4 - Other Process Uses of Carbonates | NO | NA | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.A.5 - Other (please specify) | NO | NO | NO | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.B - Chemical Industry | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 2.B.1 - Ammonia Production | NO | NA | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.B.2 - Nitric Acid Production | NA | NA | NO | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.B.3 - Adipic Acid Production | NA | NA | NO | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.B.4 - Caprolactam, Glyoxal and Glyoxylic Acid Production | NA | NA | NO | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.B.5 - Carbide Production | NO | NO | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.B.6 - Titanium Dioxide Production | NO | NA | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.B.7 - Soda Ash Production | NO | NA | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.B.8 - Petrochemical and Carbon Black Production | NO | NO | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.B.9 - Fluorochemical Production | NA | NA | NA | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 2.B.10 - Other (Please specify) | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 2.C - Metal Industry | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 2.C.1 - Iron and Steel Production | NO | NO | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.C.2 - Ferroalloys Production | NO | NO | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.C.3 - Aluminium production | NO | NA | NA | NA | NO | NA | NA | NO | NO | NO | NO | NO |
| 2.C.4 - Magnesium production | NO | NA | NA | NA | NA | NO | NA | NO | NO | NO | NO | NO |
| 2.C.5 - Lead Production | NO | NA | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.C.6 - Zinc Production | NO | NA | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.C.7 - Other (please specify) | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |

| Categories | Emissions (Gg) | | | Emissions CO2 Equivalents (Gg) | | | | Emissions (Gg) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Net $CO_2$ (1)(2) | CH4 | N2O | HFCs | PFCs | SF6 | Other halogenated gases with CO2 equivalent conversion factors (3) | Other halogenated gases without CO2 equivalent conversion factors (4) | NOx | CO | NMVOCs | SO2 |
| 2.D - Non-Energy Products from Fuels and Solvent Use | 16.221 | NO | NO | NA | NA | NA | NA | NA | NO | NO | 2.644 | NO |
| 2.D.1 - Lubricant Use | 9.064 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 2.D.2 - Paraffin Wax Use | 7.157 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 2.D.3 - Solvent Use | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 1.367 | NA |
| 2.D.4 - Other (please specify) | NO | NO | NO | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.E - Electronics Industry | NO | NO | NO | NO | NO | NO | NO | NO | NA | NA | NA | NA |
| 2.E.1 - Integrated Circuit or Semiconductor | NA | NA | NA | NO | NO | NO | NO | NO | NA | NA | NA | NA |
| 2.E.2 - TFT Flat Panel Display | NA | NA | NA | NA | NO | NO | NO | NO | NA | NA | NA | NA |
| 2.E.3 - Photovoltaics | NA | NA | NA | NA | NO | NA | NA | NO | NA | NA | NA | NA |
| 2.E.4 - Heat Transfer Fluid | NA | NA | NA | NA | NO | NA | NA | NO | NA | NA | NA | NA |
| 2.E.5 - Other (please specify) | NO | NO | NO | NO | NO | NO | NO | NO | NA | NA | NA | NA |
| 2.F - Product Uses as Substitutes for Ozone Depleting Substances | NA | NA | NA | 119.551 | NE | NA | NA | NA | NA | NA | NA | NA |
| 2.F.1 - Refrigeration and Air Conditioning | NA | NA | NA | 119.551 | NA | NA | NA | NA | NA | NA | NA | NA |
| 2.F.2 - Foam Blowing Agents | NA | NA | NA | NO | NA | NA | NA | NA | NA | NA | NA | NA |
| 2.F.3 - Fire Protection | NA | NA | NA | NE | NE | NA | NA | NA | NA | NA | NA | NA |
| 2.F.4 - Aerosols | NA | NA | NA | NE | NA | NA | NA | NA | NA | NA | NA | NA |
| 2.F.5 - Solvents | NA | NA | NA | NE | NE | NA | NA | NA | NA | NA | NA | NA |
| 2.F.6 - Other Applications (please specify) | NA | NA | NA | NO | NO | NA | NA | NA | NA | NA | NA | NA |
| 2.G - Other Product Manufacture and Use | NO | NO | 0.008 | NO | NE | NE | NO | NE | NA | NA | NA | NA |
| 2.G.1 - Electrical Equipment | NA | NA | NA | NA | NE | NE | NA | NE | NA | NA | NA | NA |
| 2.G.2 - SF6 and PFCs from Other Product Uses | NA | NA | NA | NA | NE | NE | NA | NE | NA | NA | NA | NA |

| Categories | Emissions (Gg) | | | Emissions CO2 Equivalents (Gg) | | | | | Emissions (Gg) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Net $CO_2$ (1)(2) | CH4 | N2O | HFCs | PFCs | SF6 | Other halogenated gases with CO2 equivalent conversion factors (3) | Other halogenated gases without CO2 equivalent conversion factors (4) | NOx | CO | NMVOCs | SO2 |
| 2.G.3 - N2O from Product Uses | NA | NA | 0.008 | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 2.G.4 - Other (Please specify) | NO | NO | NO | NO | NO | NO | NO | NO | NA | NA | NA | NA |
| 2.H - Other | 0.000 | 0.000 | NO | NA | NA | NA | NA | NA | 0.000 | 0.000 | 1.278 | 0.000 |
| 2.H.1 - Pulp and Paper Industry | NO | NO | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.H.2 - Food and Beverages Industry | 0.000 | 0.000 | NA | NA | NA | NA | NA | NA | 0.000 | 0.000 | 1.278 | 0.000 |
| 2.H.3 - Other (please specify) | NO | NO | NO | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 3 - Agriculture, Forestry, and Other Land Use | -116918.432 | 217.723 | 8.257 | NA | NA | NA | NA | NA | 5.426 | 349.270 | 13.544 | NO |
| 3.A - Livestock | NA | 194.921 | 0.511 | NA | NA | NA | NA | NA | NA | NA | 13.544 | NA |
| 3.A.1 - Enteric Fermentation | NA | 190.456 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 3.A.2 - Manure Management | NA | 4.466 | 0.511 | NA | NA | NA | NA | NA | NA | NA | 13.544 | NA |
| 3.B - Land | -116829.341 | NA | NO | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 3.B.1 - Forest land | -126598.050 | NA | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 3.B.2 - Cropland | NO | NA | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 3.B.3 - Grassland | 9755.939 | NA | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 3.B.4 - Wetlands | NO | NA | NO | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 3.B.5 - Settlements | 12.771 | NA | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 3.B.6 - Other Land | NO | NA | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 3.C - Aggregate sources and non-CO2 emissions sources on land | 1.256 | 22.801 | 7.746 | NA | NA | NA | NA | NA | 5.426 | 349.270 | NA | NA |
| 3.C.1 - Emissions from biomass burning | NA | 22.801 | 0.673 | NA | NA | NA | NA | NA | 5.426 | 349.270 | NA | NA |
| 3.C.2 - Liming | NO | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 3.C.3 - Urea application | 1.256 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 3.C.4 - Direct N2O Emissions from managed soils | NA | NA | 6.499 | NA | NA | NA | NA | NA | NA | NA | NA | NA |

| Categories | Emissions (Gg) | | | Emissions CO2 Equivalents (Gg) | | | | | Emissions (Gg) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Net $CO_2$ (1)(2) | CH4 | N2O | HFCs | PFCs | SF6 | Other halogenated gases with CO2 equivalent conversion factors (3) | Other halogenated gases without CO2 equivalent conversion factors (4) | NOx | CO | NMVOCs | SO2 |
| 3.C.5 - Indirect N2O Emissions from managed soils | NA | NA | 0.106 | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 3.C.6 - Indirect N2O Emissions from manure management | NA | NA | 0.468 | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 3.C.7 - Rice cultivation | NA | NO | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 3.C.8 - Other (please specify) | NA | NO | NO | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 3.D - Other | -90.347 | NO | NO | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 3.D.1 - Harvested Wood Products | -90.347 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 3.D.2 - Other (please specify) | NO | NO | NO | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 4 - Waste | 2.422 | 6.533 | 0.087 | NA | NA | NA | NA | NA | 0.496 | 8.714 | 0.588 | 0.017 |
| 4.A - Solid Waste Disposal | NA | 4.239 | NO | NA | NA | NA | NA | NA | NO | NO | 0.396 | NA |
| 4.B - Biological Treatment of Solid Waste | NA | NO | NO | NA | NA | NA | NA | NA | NO | NO | NO | NA |
| 4.C - Incineration and Open Burning of Waste | 2.422 | 1.014 | 0.013 | NA | NA | NA | NA | NA | 0.496 | 8.714 | 0.192 | 0.017 |
| 4.D - Wastewater Treatment and Discharge | NA | 1.280 | 0.074 | NA | NA | NA | NA | NA | NO | NO | 0.000 | NA |
| 4.E - Other (please specify) | NO | NO | NO | NA | NA | NA | NA | NA | NO | NO | NO | NA |
| 5 - Other | NO | NO | NE | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 5.A - Indirect N2O emissions from the atmospheric deposition of nitrogen in NOx and NH3 | NA | NA | NE | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 5.B - Other (please specify) | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | | | | | | | | | | | | |
| Memo Items (5) | | | | | | | | | | | | |
| International Bunkers | 263.112 | 0.015 | 0.007 | NA | NA | NA | NA | NA | 4.267 | 0.789 | 0.274 | 1.015 |
| 1.A.3.a.i - International Aviation (International Bunkers) | 108.698 | 0.001 | 0.003 | NA | NA | NA | NA | NA | 0.441 | 0.038 | 0.017 | 0.035 |

| Categories | Emissions (Gg) | | | Emissions CO2 Equivalents (Gg) | | | | Emissions (Gg) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Net $CO_2$ (1)(2) | CH4 | N2O | HFCs | PFCs | SF6 | Other halogenated gases with CO2 equivalent conversion factors (3) | Other halogenated gases without CO2 equivalent conversion factors (4) | NOx | CO | NMVOCs | SO2 |
| 1.A.3.d.i - International water-borne navigation (International bunkers) | 154.414 | 0.014 | 0.004 | NA | NA | NA | NA | NA | 3.825 | 0.752 | 0.257 | 0.981 |
| 1.A.5.c - Multilateral Operations | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |

# 4. Energy

## 4.1. Description of Energy sector

With regards to its Energy sector, Namibia is concerned only with activities occurring in the Fuel Combustion Category. Activities occurred under all sub-categories and GHG emissions have been estimated for all of them.

### 4.1.1. Fuel Combustion Activities (1.A)

#### 4.1.1.1. Energy Industries (1.A.1)

The Energy Industries sub-category covers the production of electricity from a mix of liquid and solid fossil fuels. The contribution of fossil fuels is however minimal in the national energy balance since the country generates a high proportion of its electricity from hydro to supplement the imported power imported from other countries. Hence, in 2019 about 71% of Namibia's demand came from the South African Power Pool (SAPP), Zambia and Zimbabwe compared to 65% in 2012. It should be noted that emissions from production of charcoal from wood has been included for the whole time series under Manufacture of Solid Fuels.

In 2019, Namibia's total installed electricity generation capacity (excluding renewables) is about 459.5 MW for a peak demand of some 633 MW normally. The biggest generation plant is the Ruacana Hydro Power station which generates about 347 MW of electricity while Van Eck Coal power station generates about 90 MW and the Anixas diesel power station at the coast generates 22.5 MW. The fossil fuel generation plants are mainly used to supplement the imports and hydro production during peak demand time. Solar and wind potential exists but are tapped only marginally up to now. The strategy is geared towards penetration of renewable energy sources and a better idea of the status can be obtained in the mitigation chapter of this report where actions are more extensively described.

#### 4.1.1.2. Manufacturing Industries and Construction (1.A.2)

Fossil fuel inputs are primarily used for generating process heat within the mining sector and in the production of cement. The two main mining companies also imported electricity directly from the neighbouring countries. The construction industry is highly diversified and detailed information was not available. There are some auto-production of electricity in this sub-category and efforts are being invested to collect data for estimating emissions from this process separately in the future. Computation of emissions has been done anew following availability of new improved datasets for wood burned for industrial purposes for years 2012 to 2015 and waste oil for period 2011 to 2015.

#### 4.1.1.3. Transport (1.A.3)

The transport sector includes domestic aviation, road transportation, railways and domestic water-borne navigation. Emissions for the three sub-categories domestic aviation, road transportation and railways have been computed in this inventory. Lack of data prevented estimation of emissions for domestic water-borne navigation which is of lesser importance compared to the other three areas of transport. Fuel supplied for international bunkering was also covered. Revised data have been used for jet kerosene under aviation and emissions have been recalculated.

#### 4.1.1.4. Other Sectors (1.A.4)

The sub-categories included under Other Sectors, namely, Residential and Fishing, were the two main GHG contributors. AD for Commercial/Institutional, Stationary combustion and Off-road vehicles and other machinery within the Agriculture and Forestry sectors were not available. It should however be pointed out that the fuels consumed in these sub-categories have been accounted for under other combustion activities within the national energy balance of the country. So, there is really no underestimation in the inventory.

The fuel mix used within the residential sector by households for cooking varied over the inventory period following urbanisation and increase in purchasing power resulting in households shifting from wood and charcoal to other energy sources. In 2015, about 49% of the households used wood/charcoal, about 37% used electricity and the remainder used mainly LPG (Liquefied Petroleum Gas). Paraffin and waxes (around 13%), batteries (around 32%) and electricity (about 48%) were the main sources of energy used for lighting. About 37% of households consumed wood/charcoal for heating purposes and 31% had recourse to electricity. Following the availability of new information on use of wood/charcoal for heating purposes, the AD for the residential sector have been readjusted and emissions recalculated for the whole time series.

Fishing is an important activity in Namibia with a fleet of some 160 fishing vessels (*Ministry of Works and Transport, Maritime Affairs, 2010*) operating out of a registered total of 208. Particular attention was paid to this sub-category to collect AD and make estimates of emissions.

#### 4.1.1.5. Non-Specified (1.A.5)

Fossil fuel burned in this sector was considered confidential and the allocation from the energy balance not accounted for under other sectors was combusted under this sub-category for estimating GHG emissions.

#### 4.1.1.6. Memo items

International bunkers included international aviation and navigation according to the IPCC Guidelines. Both activity areas were covered, and they consumed significant amounts of fossil fuel imported in the country. The emissions have been computed and reported in this inventory.

## 4.2. Methods

It is Good Practice to estimate emissions using both the Reference and Sectoral approaches. During this exercise, emission estimates were computed using both approaches. The top down Reference approach was carried out using import, export, production and stock change data that constituted the basis for producing the national energy balance. The bottom up Sectoral Approach generally involved the quantification of fuel consumption from end use data by the different sector source categories. Thereafter, the IPCC conversion and EFs were adopted to compile GHG emissions. The Sectoral approach covered all the IPCC source categories where AD were available. AD could not be traced for a few minor sub-categories such as Agriculture, Forestry, Commercial and Institutional but this does not really affect the quality of the inventory as the fossil fuels consumed in these sub-categories have been allocated and burned in other categories.

The basic equations used to estimate GHG emissions are given below:

$$\textbf{Emissions}_{\text{GHG fuel}} = \textbf{Fuel Consumption}_{\text{fuel}} \times \textbf{Emission Factor}_{\text{GHG fuel}}$$

**Where**

| | |
|---|---|
| **Emissions** $_{\text{GHG, fuel}}$ | = emissions of a given GHG by type of fuel (kg GHG) |
| **Fuel Consumption** $_{\text{fuel}}$ | = amount of fuel combusted (TJ) |
| **Emission Factor** $_{\text{GHG, fuel}}$ | = default emission factor of a given GHG by type of fuel (kg gas/TJ). For $CO_2$, it includes the carbon oxidation factor, assumed to be 1. |

## 4.3. Activity Data

AD for working out the reference approach was obtained from the energy database of the NSA on imports and exports of energy products. For the bottom up sectoral approach, AD were sourced from the end-users of fossil fuels. Data on biomass used were derived from data on consumption of different fuels by households collected in the censuses conducted by the NSA. The same approach was used to determine the amount of charcoal used. The data collection covered all solid, liquid and gaseous fossil fuels, fuelwood and charcoal. In cases where data were missing or to correct for outliers, the inventory compilers resorted to international databases including those from IEA, the UN and FAO among others. These sources provided most of the AD required for the period 1990 to 2002 as the country was still in the process of setting up its statistical organisation after gaining independence but to a lesser extent for the period 2003 to 2016. Missing data for these years were thus obtained from the international databases or from extrapolation of the available time series. Where necessary, proxies such as population, GDP and production data were used to ascertain the generated data.

A summary of data sources of the country is given in Table 4.1.

**Table 4.1 - Summary of data sources**

| Category | Fuel type | Data source |
|---|---|---|
| Energy industries | Fuel oil | Nampower |
| | Coal | Nampower |
| Mining | Gasolene/Diesel | ECB Project “Energy Policy, Regulatory Framework and Energy Future of Namibia (2011-2013)”. |
| | Coal | ECB Project “Energy Policy, Regulatory Framework and Energy Future of Namibia (2011-2013)”. |
| | Waste oil | National statistics. |
| Other manufacturing | Gasoline/Diesel | Ministry of Industrialization, Trade and SME Development. |
| Domestic aviation | Aviation Gasoline | Airport profile data and national statistics |
| | Jet kerosene | Airport profile data and national statistics. |
| Road Transport | Gasoline/Diesel | Gasoline and diesel estimated for the different IPCC vehicles classes in the fleet, mileage run by each and fuel consumption indicators for respective years |
| | LPG | Import and export data from NSA |
| Railways | Diesel/residual | TransNamib |
| Residential | Kerosene | Import and export data from NSA. |
| | LPG | Import and export data from NSA. |

| Category | Fuel type | Data source |
|---|---|---|
| | Wax candles | Ministry of Industrialization, Trade and SME Development and import and export data from NSA |
| | Wood fuel | Derived from NSA census data. |
| | Charcoal | Derived from NSA census data and import and export data from NSA. |
| Agriculture/ fishing | Gasoline | Import and export data from NSA. |
| | Diesel | National statistics on consumption and import and export from NSA. |
| International aviation bunkers | Jet kerosene | Airport profile data and national statistics. |
| International marine bunkers | Diesel | Ministry of Works and Transport, Maritime Affairs. |
| | Gasoline | National statistics. |
| | Residual fuel oil | SNC and National statistics. |

AD were not always available and in the format required as well as at the level of disaggregation needed for the sectors. This is because the country is still in the process of putting in place its GHG inventory management system. Gaps were filled using statistical methods such as trend analysis, interpolation and extrapolation as appropriate. In some cases, fuels had to be allocated or determined according to the activity area. One such example is the amount of fuel used in the fishing sector which is directly related to fishing vessel campaigns and fish catch. Fuel used for sectors like Agriculture, Forestry and Institutional amongst others could neither be traced nor generated. Thus, fuels from these sectors were eventually allocated in different sectors based on amounts distributed and consumed. AD used for the Energy Sector is provided in **Error! Reference source not found.**.

## Table 4.2 - Activity data (tonnes) used for Sectoral Approach of Energy Sector

| Categories | Type of fuel | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Energy generation | HFO and LFO | 212.2 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 53 | 119 | 131 | 628 | 130 | 1239 | 2610 | 2569 | 554 | 774 | 1123 | 1230 | 5616 | 2914 | 1508 | 254 | 309 |
| | Bitum. coal | 8500 | 9441 | 10381 | 11322 | 12262 | 13203 | 14143 | 15084 | 16024 | 16965 | 2926 | 3609 | 18 | 7942 | 718 | 20384 | 63877 | 76599 | 95876 | 57453 | 13105 | 3735 | 32344 | 2575 | 275 | 8116 | 35,196 |
| Mining | Gasoline | 300000 | 300000 | 300000 | 300000 | 300000 | 300000 | 300000 | 300000 | 300000 | 300000 | 300000 | 300000 | 300000 | 300000 | 301044 | 294031 | 320779 | 374117 | 523727 | 693161 | 621187 | 465524 | 471321 | 549841 | 541410 | 645763 | 683445 |
| | Gasoil/Diesel | 2454 | 2454 | 2454 | 2454 | 2454 | 2454 | 2454 | 2454 | 2454 | 2454 | 2454 | 2454 | 2454 | 2454 | 2454 | 2454 | 2454 | 2454 | 2454 | 2454 | 2454 | 2454 | 2454 | 2454 | 2454 | 2454 | 2454 |
| | Bitum. coal | 5,718 | 6356 | 6995 | 7633 | 8271 | 8909 | 9548 | 10186 | 10824 | 11463 | 11778 | 11508 | 10994 | 11938 | 15007 | 14771 | 17309 | 23244 | 25310 | 22536 | 21145 | 19767 | 21149 | 15464 | 16201 | 16937 | 17673 |
| | Waste oil | 28887 | 29202 | 29518 | 29834 | 30150 | 30465 | 30781 | 31097 | 31413 | 31728 | 33479 | 39040 | 25800 | 38040 | 38040 | 32600 | 32840 | 28400 | 23960 | 31160 | 36160 | 49640 | 36148 | 36464 | 36780 | 37096 | 37411 |
| | Other petroleum pdts | 427 | 427 | 427 | 427 | 427 | 427 | 427 | 427 | 427 | 427 | 483 | 224 | 618 | 1011 | 2050 | 3089 | 3483 | 5599 | 7440 | 7702 | 6948 | 7,519 | 7,796 | 7,975 | 9,105 | 9,890.8 | 10,343 |
| | Petroleum coke | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 20 | 0 | 1 | 0 | 43 | 19 | 26 | 205 | 148 | 194 | 154 | 101 | 1389 | 1418 | 890 | 933 | 215 | 418 | 1506 |
| Other manufacturing | Gasoline | 134 | 134 | 134 | 134 | 134 | 134 | 134 | 134 | 0 | 582 | 197 | 0 | 18 | 2 | 211 | 0 | 816 | 0 | 0 | 0 | 155 | 281 | 0 | 0 | 24 | 0 | 0 |
| | Gasoil/Diesel | 157 | 161 | 166 | 170 | 175 | 180 | 184 | 188 | 193 | 206 | 218 | 212 | 221 | 223 | 239 | 231 | 232 | 239 | 226 | 253 | 257 | 259 | 271 | 275 | 269 | 276 | 281 |
| | Wood/wood waste | 193 | 204 | 215 | 226 | 238 | 249 | 261 | 272 | 283 | 296 | 317 | 326 | 387 | 371 | 396 | 395 | 404 | 398 | 408 | 421 | 440 | 405 | 483 | 493 | 475 | 484 | 494 |
| Civil aviation | Aviation Gasoline | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 27,000 | 30,000 | 27,000 | 27,000 | 9,356 |
| | Jet kerosene | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 9,091 |
| Road transportation | Gasoline | 2557 | 2596 | 2635 | 2674 | 2712 | 2751 | 2790 | 2829 | 2868 | 2907 | 3012 | 3043 | 3074 | 3105 | 3136 | 3167 | 3210 | 3210 | 3210 | 3210 | 3596 | 3413 | 3452 | 3491 | 3530 | 3568 | 3607 |
| | Diesel | 1302 | 1433 | 1564 | 1694 | 1825 | 1956 | 2087 | 2218 | 2348 | 2479 | 3074 | 3105 | 3136 | 3168 | 3200 | 3232 | 3264 | 3297 | 3330 | 3363 | 3456 | 5652 | 4554 | 4554 | 4554 | 4554 | 4554 |
| | LPG | 129824 | 136657 | 143849 | 151421 | 159390 | 169585 | 179780 | 189975 | 200169 | 210364 | 220559 | 239093 | 236045 | 268509 | 283498 | 300461 | 318194 | 331730 | 294461 | 308100 | 333283 | 290682 | 294559 | 301334 | 345808 | 357969 | 371794 |
| | Lubricant | 40175 | 47265 | 55606 | 65419 | 76963 | 92407 | 107851 | 123295 | 138739 | 154183 | 169627 | 192004 | 196915 | 232291 | 249491 | 269389 | 286920 | 304652 | 286210 | 313149 | 348809 | 347386 | 374068 | 381972 | 437331 | 498178 | 514037 |
| Railways | Gasoil/Diesel | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 72 | 276 | 496 | 715 | 500 | 500 | 500 | 500 | 500 | 500 |
| | Fuel oil | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 5 | 5 | 6 | 7 | 7 | 7 | 7 | 7 | 8 | 7 | 7 | 8 | 8 | 7 |
| Residential | Other Kerosene | 9482 | 9862 | 10242 | 10623 | 11003 | 11383 | 11763 | 12143 | 12524 | 12904 | 12900 | 13607 | 14314 | 15021 | 15728 | 16435 | 16808 | 17207 | 16022 | 15710 | 6571 | 5948 | 6416 | - | - | - | |
| | LPG | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 9857 | 8922 | 9624 | 14944 | 15570 | 15570 | 15570 |

| Categories | Type of fuel | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Paraffin wax | 4717 | 4608 | 4499 | 4391 | 4282 | 4173 | 4064 | 3956 | 3847 | 3738 | 3316 | 3283 | 3251 | 3219 | 3187 | 3155 | 3124 | 3093 | 2700 | 2357 | 2057 | 1796 | 1568 | 1369 | 1195 | 1043 | 910 |
| | Wood fuel | 5000 | 5000 | 5000 | 6000 | 6000 | 7000 | 7000 | 8000 | 7395 | 6987 | 5705 | 7798 | 9781 | 9059 | 6085 | 9999 | 9461 | 8923 | 8419 | 7915 | 7422 | 7348 | 6050 | 6406 | 8597 | 10787 | 12261 |
| | Charcoal | 24000 | 24000 | 24000 | 24000 | 24000 | 24000 | 24000 | 24000 | 24000 | 24000 | 23532 | 21855 | 23661 | 24265 | 27354 | 24612 | 23256 | 23303 | 27700 | 28791 | 22023 | 24000 | 24000 | 24000 | 24000 | 24000 | 24000 |
| **Fishing** | Gasoline | 376750 | 384290 | 386788 | 389282 | 391773 | 394261 | 396745 | 399226 | 401703 | 404178 | 406650 | 409119 | 413402 | 417700 | 422012 | 426337 | 430675 | 435024 | 439383 | 443752 | 448130 | 454163 | 449022 | 443610 | 437921 | 431947 | 425680 |
| | Gasoil/Diesel | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 |
| **Non-specified** | Gasoline | 1430 | 1600 | 1770 | 1940 | 2110 | 2280 | 2450 | 2620 | 2790 | 2960 | 3300 | 3470 | 3640 | 3810 | 3980 | 4150 | 4320 | 4490 | 4660 | 4830 | 5000 | 5170 | 5340 | 3871 | 4023 | 4176 | 4329 |
| | Diesel | 76004 | 85014 | 90100 | 99546 | 112626 | 85741 | 85741 | 71935 | 87921 | 101000 | 98000 | 107000 | 128000 | 132000 | 121000 | 116000 | 90748 | 71932 | 65660 | 75460 | 78596 | 76636 | 93100 | 66836 | 81340 | 80425 | 80425 |
| **International aviation** | Jet kerosene | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 241 | 273 | 281 | 325 | 578 | 743 |
| **International marine bunkers** | Gasoil/Diesel | 2436 | 2866 | 3372 | 3967 | 4667 | 5603 | 6540 | 7476 | 8412 | 9349 | 10285 | 11576 | 11812 | 12967 | 13442 | 13512 | 13884 | 13879 | 11589 | 11987 | 12807 | 13742 | 15576 | 16010 | 18525 | 32995 | 42391 |
| | Gasoline | 19949.9 | 20554 | 21159 | 21763 | 22368 | 22972 | 23577 | 24181 | 24786 | 25390 | 27665 | 27945 | 28227 | 28512 | 28800 | 29088 | 29379 | 29673 | 29969 | 30269 | 31120 | 37826 | 34473 | 34473 | 34473 | 34473 | 34473 |
| | Residual Fuel Oil | 30281 | 29781 | 29281 | 28781 | 28281 | 27781 | 27280 | 26780 | 26280 | 25780 | 25247 | 24672 | 24039 | 23407 | 22774 | 22142 | 21509 | 20876 | 20244 | 19611 | 18979 | 18921 | 18921 | 18921 | 18921 | 18921 | 18921 |

## 4.4. Emission factors

Namibia does not have national EFs for the Energy sector. Thus, the IPCC default EFs were adopted to compute GHG emissions. The EFs are listed in Table 4.3.

**Table 4.3 - List of emission factors (kg/TJ) used in the Energy sector**

| Fuel | Emission factor | | | | | |
|---|---|---|---|---|---|---|
| | $CO_2$ | $CH_4$ | $N_2O$ | $CO_2$ | $CH_4$ | $N_2O$ |
| Motor Gasoline | 69,300 | 3.0 | 0.6 | Vol. 2, table 2.3 | Vol. 2, table 2.3 | Vol. 2, table 2.3 |
| | "" | 33.0 | 3.2 | Vol. 2, table 3.2.1 | Vol. 2, table 3.2.2 | Vol. 2, table 3.2.2 |
| | "" | 7.0 | 2.0 | Vol. 2, table 3.5.2 | Vol. 2, table 3.5.3 | Vol. 2, table 3.5.3 |
| | "" | 10.0 | 0.6 | Vol. 2, table 2.5 | Vol. 2, table 2.5 | Vol. 2, table 2.5 |
| Aviation gasoline | 70,000 | 0.5 | 2.0 | Vol. 2, table 3.6.4 | Vol. 2, table 3.6.5 | Vol. 2, table 3.6.5 |
| Jet kerosene | 71,500 | 0.5 | 2.0 | Vol. 2, table 3.6.4 | Vol. 2, table 3.6.5 | Vol. 2, table 3.6.5 |
| Other kerosene | 71,900 | 10.0 | 0.6 | Vol. 2, table 2.5 | Vol. 2, table 2.5 | Vol. 2, table 2.5 |
| Gasoil/Diesel | 74,100 | 3.0 | 0.6 | Vol. 2, table 2.3 | Vol. 2, table 2.3 | Vol. 2, table 2.3 |
| | "" | 3.9 | 3.9 | Vol. 2, table 3.2.1 | Vol. 2, table 3.2.2 | Vol. 2, table 3.2.2 |
| | "" | 4.15 | 28.6 | Vol. 2, table 3.4.1 | Vol. 2, table 3.4.1 | Vol. 2, table 3.4.1 |
| | "" | 7.0 | 2.0 | Vol. 2, table 3.5.2 | Vol. 2, table 3.5.3 | Vol. 2, table 3.5.3 |
| | "" | 10.0 | 0.6 | Vol. 2, table 2.5 | Vol. 2, table 2.5 | Vol. 2, table 2.5 |
| Residual fuel oil | 77,400 | 3.0 | 0.6 | Vol. 2, table 2.2 | Vol. 2, table 2.2 | Vol. 2, table 2.2 |
| | "" | 7.0 | 2.0 | Vol. 2, table 3.5.2 | Vol. 2, table 3.5.3 | Vol. 2, table 3.5.3 |
| | "" | 4.15 | 28.6 | Vol. 2, table 3.2.1 | Vol. 2, table 3.4.1 | Vol. 2, table 3.4.1 |
| Liquefied petroleum gases | 63,100 | 5.0 | 0.1 | Vol. 2, table 2.5 | Vol. 2, table 2.5 | Vol. 2, table 2.5 |
| Liquefied petroleum gases | 63,100 | 62.0 | 0.2 | Vol. 2, table 3.2.1 | Vol. 2, table 3.2.2 | Vol. 2, table 3.2.2 |
| Petroleum coke | 97,500 | 3.0 | 0.6 | Vol. 2, table 2.3 | Vol. 2, table 2.3 | Vol. 2, table 2.3 |
| Paraffin waxes | 73,300 | 10.0 | 0.6 | Vol. 2, table 2.5 | Vol. 2, table 2.5 | Vol. 2, table 2.5 |
| Other petroleum products | 73,300 | 3.0 | 0.6 | Vol. 2, table 2.3 | Vol. 2, table 2.3 | Vol. 2, table 2.3 |
| Other bituminous coal | 94,600 | 1.0 | 1.5 | Vol. 2, table 2.2 | Vol. 2, table 2.2 | Vol. 2, table 2.2 |
| | "" | 10 | 1.5 | Vol. 2, table 2.3 | Vol. 2, table 3.4.1 | Vol. 2, table 3.4.1 |
| Natural gas liquids | 64,200 | 10 | 0.6 | Vol. 2, table 2.5 | Vol. 2, table 2.5 | Vol. 2, table 2.5 |
| Waste oils | 73,300 | 30.0 | 4.0 | Vol. 2, table 2.3 | Vol. 2, table 2.2 | Vol. 2, table 2.2 |
| Wood fuel | 112,000 | 300.0 | 4.0 | Vol. 2, table 2.5 | Vol. 2, table 2.5 | Vol. 2, table 2.5 |
| Charcoal | 112,000 | 200.0 | 1.0 | Vol. 2, table 2.5 | Vol. 2, table 2.5 | Vol. 2, table 2.5 |

## 4.5. Emission estimates

### 4.5.1. Reference approach

***Comparison of the Sectoral approach (SA) with the Reference approach (RA)***

The results, covering $CO_2$ only, differed between the years for the two approaches with higher emissions for the reference approach for all years as expected. The difference varied from -15.8 to 20.8 over the years. The few large differences between the two approaches could possibly be due to rolling stocks from one year to the next as this is difficult to track within the country's context. It is worth highlighting that the country is in the process of making annual energy balances that will help refine AD for this sector.

Table 4.4 - Comparison of the Reference and Sectoral Approaches (Gg $CO_2$) (1990 - 2016)

| Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reference approach (Gg) | 1,001 | 992 | 1,086 | 1,102 | 1,289 | 1,576 | 1,687 | 1,736 | 1,791 | 1,714 | 1,643 | 2,092 | 1,940 | 2,184 |
| Sectoral approach (Gg) | 1,044 | 1,125 | 1,198 | 1,295 | 1,408 | 1,415 | 1,506 | 1,555 | 1,695 | 1,827 | 1,868 | 2,046 | 2,093 | 2,379 |
| Differences (%) | -4.1 | -11.8 | -9.4 | -14.9 | -8.4 | 11.4 | 12.1 | 11.7 | 5.7 | -6.2 | -12.0 | 2.3 | -7.3 | -8.2 |

| Year | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reference approach (Gg) | 2,153 | 2,194 | 2,306 | 2,638 | 3,192 | 2,997 | 2,800 | 2,812 | 3,245 | 3,354 | 3,220 | 3,920 | 4,053 |
| Sectoral approach (Gg) | 2,444 | 2,590 | 2,740 | 2,822 | 2,671 | 2,748 | 2,837 | 2,713 | 2,918 | 2,776 | 3,147 | 3,450 | 3,649 |
| Differences (%) | -11.9 | -15.3 | -15.8 | -6.5 | 19.5 | 9.0 | -1.3 | 3.6 | 11.2 | 20.8 | 2.3 | 13.6 | 11.1 |

### 4.5.2. Sectoral approach

Only one category is concerned with emissions in the Energy sector, namely Fuel Combustion activities. Total aggregated emissions for the three direct GHGs are provided in Table 4.5 while the share of emissions by category is depicted in Figure 4.1 for the five IPCC sub-categories falling under Fuel Combustion activities for the time series 1990 to 2016. Total emissions from Fuel Combustion Activities varied from 1,117 Gg $CO_2$-eq in 1990 to 3,791 Gg $CO_2$-eq in 2016. The emissions varied between the years under review as fuel combustion is related to economic activity and other factors. However, the trend is for an increase in consumption of fossil fuels from 1990 to 2016. The sharp increase in the emissions of the Non-Specified sub-category from 2014 to 2015 is attributed to the increase in the number of vehicles recorded in this class.

The sub-categories included under Other Sectors were Residential and Fishing. AD for Commercial/Institutional, Stationary combustion and Off-road vehicles and other machinery within the Agriculture and Forestry sectors were not available. It should however be pointed out that the fuels consumed in these sub-categories have been accounted for under other combustion activities within the national energy balance of the country. So, there is no underestimation in the inventory.

Table 4.5 - Emissions for Fuel Combustion Activities (Gg $CO_2$-eq) (1990 - 2016)

| Year | 1 - Energy | 1.A.1 - Energy Industries | 1.A.2 - Manufacturing Industries and Construction | 1.A.3 - Transport | 1.A.4 - Other Sectors | 1.A.5 - Non-specified |
|---|---|---|---|---|---|---|
| 1990 | 1,116.9 | 30.3 | 99.7 | 584.5 | 394.5 | 7.9 |
| 1991 | 1,199.8 | 32.6 | 102.6 | 630.9 | 424.5 | 9.3 |
| 1992 | 1,274.9 | 34.9 | 105.4 | 682.4 | 441.2 | 10.9 |
| 1993 | 1,373.2 | 37.2 | 108.3 | 739.9 | 474.9 | 12.9 |
| 1994 | 1,487.7 | 39.5 | 111.2 | 804.6 | 517.3 | 15.1 |
| 1995 | 1,497.0 | 41.8 | 114.0 | 888.3 | 434.7 | 18.2 |
| 1996 | 1,589.7 | 44.1 | 116.9 | 972.4 | 435.1 | 21.2 |
| 1997 | 1,641.2 | 46.4 | 119.8 | 1,056.4 | 394.4 | 24.2 |
| 1998 | 1,782.9 | 48.7 | 122.2 | 1,140.4 | 444.2 | 27.3 |
| 1999 | 1,918.1 | 51.0 | 126.9 | 1,224.4 | 485.4 | 30.3 |
| 2000 | 1,960.0 | 16.1 | 131.3 | 1,308.8 | 470.6 | 33.3 |
| 2001 | 2,141.9 | 18.0 | 142.7 | 1,442.3 | 501.4 | 37.5 |

| Year | 1 - Energy | 1.A.1 - Energy Industries | 1.A.2 - Manufacturing Industries and Construction | 1.A.3 - Transport | 1.A.4 - Other Sectors | 1.A.5 - Non-specified |
|---|---|---|---|---|---|---|
| 2002 | 2,189.8 | 9.2 | 110.1 | 1,451.4 | 580.9 | 38.3 |
| 2003 | 2,481.6 | 30.2 | 144.2 | 1,670.9 | 594.2 | 42.0 |
| 2004 | 2,549.2 | 11.0 | 158.0 | 1,776.5 | 560.2 | 43.6 |
| 2005 | 2,698.9 | 62.5 | 146.8 | 1,897.1 | 548.7 | 43.8 |
| 2006 | 2,852.8 | 174.2 | 159.2 | 2,011.2 | 463.1 | 45.0 |
| 2007 | 2,938.4 | 206.9 | 171.2 | 2,113.0 | 402.3 | 45.0 |
| 2008 | 2,788.2 | 252.2 | 172.3 | 1,932.5 | 393.5 | 37.6 |
| 2009 | 2,873.4 | 163.6 | 181.9 | 2,062.4 | 426.6 | 38.9 |
| 2010 | 2,963.5 | 53.8 | 191.8 | 2,261.1 | 415.2 | 41.5 |
| 2011 | 2,832.4 | 26.6 | 222.7 | 2,122.8 | 415.0 | 45.3 |
| 2012 | 3,040.7 | 110.7 | 193.4 | 2,222.3 | 463.0 | 51.4 |
| 2013 | 2,900.2 | 31.5 | 176.8 | 2,265.0 | 374.2 | 52.8 |
| 2014 | 3,276.4 | 21.2 | 181.1 | 2,586.6 | 426.4 | 61.1 |
| 2015 | 3,587.1 | 39.5 | 187.2 | 2,822.2 | 429.3 | 108.8 |
| 2016 | 3,790.8 | 107.2 | 195.9 | 2,914.9 | 433.1 | 139.8 |

**Other sectors: include Residential and Fishing**

Transport contributed the major share of these emissions, some 78% in 2016. Emissions from transport increased 5 times over these 27 years. The Other Sectors category was the second highest emitter after transport with 11.4% while emissions from Manufacturing Industries and Construction stood at 5.2% of total aggregated emissions in the same year. Energy Industries emissions varied widely because local electricity generation serves only to supplement import deficits and emissions from that category hit a maximum in 2008.

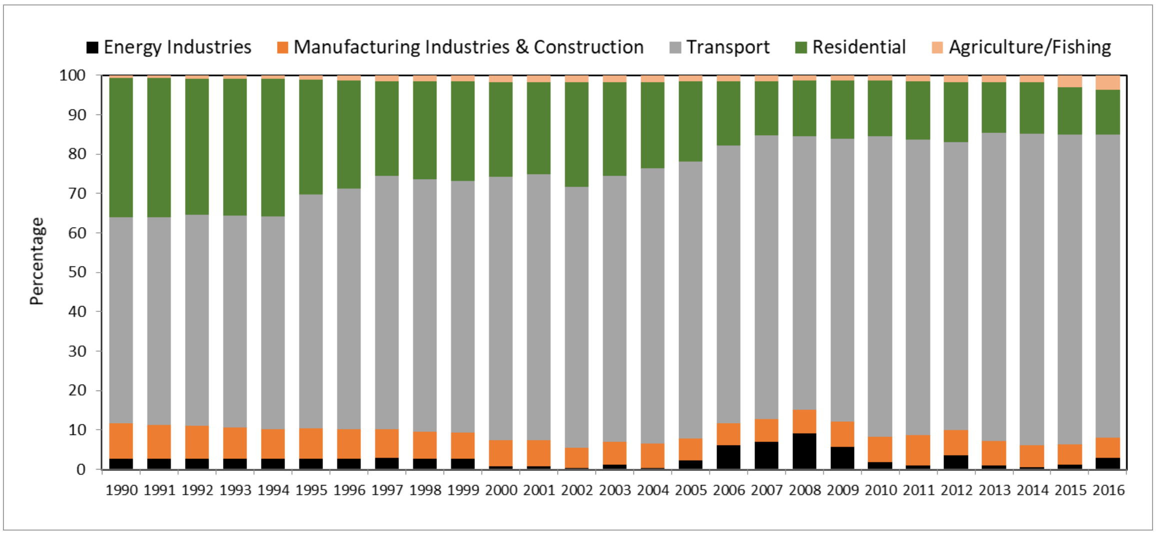


**Figure 4.1- Share of GHG emissions (Gg $CO_2$-eq) by Energy sub-category (1990 - 2016)**

Out of the nine Energy sub-categories, Road transportation remained the major contributor of emissions (Table 4.6), expressed in terms of Gg $CO_2$-eq, followed by Fishing. Emissions from the Road transportation sub-category increased from 539 Gg $CO_2$-eq in 1990 to reach 2,835 Gg $CO_2$-eq in 2016 representing 75% of total emissions of the Energy sector.

Table 4.6 - GHG emissions (Gg $CO_2$-eq) by Energy sub-category (1990 - 2016)

| Year | 1 - Energy | 1.A.1.a.i - Electricity Generation | 1.A.1.c.i - Manufacture of Solid Fuels | 1.A.2.i - Mining (excluding fuels) and Quarrying | 1.A.2.m - Non-specified Industry | 1.A.3.a - Civil Aviation | 1.A.3.b - Road Transport ation | 1.A.3.c - Railways | 1.A.4.b - Residen tial | 1.A.4.c.iii - Fishing (mobile combustion) | 1.A.5.b.iii - Mobile (Other) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 1,116.9 | 21.5 | 8.8 | 98.6 | 1.1 | 12.1 | 538.5 | 33.9 | 146.6 | 247.9 | 7.9 |
| 1991 | 1,199.8 | 23.8 | 8.8 | 101.4 | 1.2 | 12.7 | 583.0 | 35.2 | 147.2 | 277.3 | 9.3 |
| 1992 | 1,274.9 | 26.1 | 8.8 | 104.2 | 1.2 | 13.2 | 632.6 | 36.6 | 147.1 | 294.1 | 10.9 |
| 1993 | 1,373.2 | 28.4 | 8.8 | 107.1 | 1.3 | 13.8 | 688.2 | 37.9 | 150.1 | 324.9 | 12.9 |
| 1994 | 1,487.7 | 30.8 | 8.8 | 109.9 | 1.3 | 14.6 | 750.7 | 39.3 | 150.0 | 367.3 | 15.1 |
| 1995 | 1,497.0 | 33.1 | 8.8 | 112.7 | 1.4 | 14.8 | 832.9 | 40.7 | 153.0 | 281.7 | 18.2 |
| 1996 | 1,589.7 | 35.4 | 8.8 | 115.5 | 1.4 | 15.4 | 915.0 | 42.0 | 152.9 | 282.2 | 21.2 |
| 1997 | 1,641.2 | 37.7 | 8.8 | 118.3 | 1.4 | 15.9 | 997.1 | 43.4 | 155.8 | 238.5 | 24.2 |
| 1998 | 1,782.9 | 40.0 | 8.8 | 120.7 | 1.5 | 16.4 | 1,079.2 | 44.7 | 154.0 | 290.3 | 27.3 |
| 1999 | 1,918.1 | 42.3 | 8.8 | 125.3 | 1.6 | 17.0 | 1,161.4 | 46.1 | 152.7 | 332.7 | 30.3 |
| 2000 | 1,960.0 | 7.3 | 8.8 | 129.6 | 1.7 | 19.2 | 1,243.5 | 46.1 | 146.4 | 324.1 | 33.3 |
| 2001 | 2,141.9 | 9.2 | 8.8 | 141.0 | 1.7 | 19.4 | 1,374.3 | 48.6 | 147.9 | 353.5 | 37.5 |
| 2002 | 2,189.8 | 0.5 | 8.8 | 108.2 | 1.9 | 19.6 | 1,380.6 | 51.1 | 159.6 | 421.3 | 38.3 |
| 2003 | 2,481.6 | 21.5 | 8.8 | 142.4 | 1.9 | 19.8 | 1,597.4 | 53.6 | 159.6 | 434.6 | 42.0 |
| 2004 | 2,549.2 | 2.2 | 8.8 | 156.0 | 2.0 | 20.0 | 1,700.3 | 56.2 | 160.3 | 399.9 | 43.6 |
| 2005 | 2,698.9 | 53.9 | 8.6 | 144.9 | 2.0 | 20.2 | 1,818.2 | 58.7 | 164.3 | 384.4 | 43.8 |
| 2006 | 2,852.8 | 164.9 | 9.4 | 157.2 | 2.0 | 20.4 | 1,930.8 | 60.0 | 159.1 | 304.0 | 45.0 |
| 2007 | 2,938.4 | 196.0 | 10.9 | 169.2 | 2.0 | 20.5 | 2,031.0 | 61.5 | 158.0 | 244.3 | 45.0 |
| 2008 | 2,788.2 | 236.9 | 15.3 | 170.3 | 2.0 | 20.6 | 1,854.7 | 57.2 | 168.8 | 224.7 | 37.6 |
| 2009 | 2,873.4 | 143.4 | 20.2 | 179.8 | 2.1 | 20.7 | 1,985.6 | 56.1 | 170.0 | 256.6 | 38.9 |
| 2010 | 2,963.5 | 35.7 | 18.1 | 189.6 | 2.2 | 22.2 | 2,181.0 | 57.9 | 148.0 | 267.2 | 41.5 |
| 2011 | 2,832.4 | 13.0 | 13.6 | 220.6 | 2.1 | 28.7 | 2,041.8 | 52.4 | 153.5 | 261.5 | 45.3 |
| 2012 | 3,040.7 | 97.0 | 13.7 | 190.2 | 3.2 | 25.3 | 2,140.5 | 56.5 | 148.3 | 314.7 | 51.4 |
| 2013 | 2,900.2 | 15.5 | 16.0 | 173.5 | 3.3 | 25.4 | 2,187.4 | 52.1 | 148.1 | 226.0 | 52.8 |
| 2014 | 3,276.4 | 5.4 | 15.8 | 178.0 | 3.1 | 25.5 | 2,506.7 | 54.3 | 153.4 | 273.0 | 61.1 |
| 2015 | 3,587.1 | 20.7 | 18.8 | 184.0 | 3.2 | 25.7 | 2,742.2 | 54.3 | 158.8 | 270.5 | 108.8 |
| 2016 | 3,790.8 | 87.3 | 19.9 | 191.7 | 4.2 | 25.8 | 2,834.8 | 54.3 | 162.1 | 271.0 | 139.8 |

The evolution of emissions of direct and indirect GHGs in the Energy sector is presented in Table 4.7. $CO_2$ contributed a major part of the emissions of the direct gases followed by $CH_4$ and $N_2O$ throughout the full time series 1990 to 2016. The contribution of $CO_2$ increased over the same period from 94% in 1990 to 96% in 2016 (Figure 4.2) of total aggregated emissions of the direct GHGs of the Energy sector.

Among the indirect gases (Table 4.7), CO was the main gas emitted over the time series followed by $NO_x$ and NMVOCs. Over the time series, the emissions increased very slightly for the three indirect GHGs, due to increased economic activity. Emissions of $SO_2$ varied between 1.9 Gg and 4.3 Gg.

**Table 4.7 - Emissions (Gg) by gas for the Energy sector (1990 - 2016)**

| Year | Gg $CO_2$-eq | | | Gg | | | |
|---|---|---|---|---|---|---|---|
| | $CO_2$ | $CH_4$ | $N_2O$ | $NO_x$ | CO | NMVOC | $SO_2$ |
| 1990 | 1,044.2 | 2.2 | 0.1 | 10.4 | 46.6 | 6.5 | 1.9 |
| 1991 | 1,124.9 | 2.3 | 0.1 | 11.5 | 48.2 | 6.7 | 2.1 |
| 1992 | 1,198.4 | 2.3 | 0.1 | 12.2 | 49.5 | 6.9 | 2.2 |
| 1993 | 1,295.0 | 2.3 | 0.1 | 13.4 | 50.9 | 7.1 | 2.4 |
| 1994 | 1,407.5 | 2.4 | 0.1 | 14.9 | 52.4 | 7.4 | 2.7 |
| 1995 | 1,415.1 | 2.4 | 0.1 | 13.4 | 54.0 | 7.5 | 2.2 |
| 1996 | 1,505.6 | 2.4 | 0.1 | 14.0 | 55.7 | 7.7 | 2.2 |
| 1997 | 1,555.2 | 2.4 | 0.1 | 13.5 | 57.3 | 7.9 | 2.0 |
| 1998 | 1,694.5 | 2.5 | 0.1 | 15.4 | 59.1 | 8.2 | 2.3 |
| 1999 | 1,827.3 | 2.5 | 0.1 | 17.0 | 60.9 | 8.4 | 2.6 |
| 2000 | 1,867.5 | 2.5 | 0.1 | 17.3 | 62.8 | 8.7 | 2.3 |
| 2001 | 2,045.9 | 2.6 | 0.1 | 18.7 | 65.5 | 8.6 | 2.5 |
| 2002 | 2,092.8 | 2.6 | 0.1 | 20.5 | 65.7 | 8.7 | 2.8 |
| 2003 | 2,378.9 | 2.7 | 0.1 | 22.3 | 70.4 | 9.2 | 3.1 |
| 2004 | 2,443.8 | 2.7 | 0.2 | 22.3 | 73.5 | 9.6 | 3.6 |
| 2005 | 2,590.3 | 2.8 | 0.2 | 22.7 | 75.9 | 9.9 | 3.8 |
| 2006 | 2,740.3 | 2.8 | 0.2 | 21.7 | 78.5 | 10.2 | 4.3 |
| 2007 | 2,821.7 | 2.9 | 0.2 | 21.1 | 80.6 | 10.5 | 4.1 |
| 2008 | 2,670.8 | 2.9 | 0.2 | 19.9 | 76.5 | 10.0 | 4.3 |
| 2009 | 2,748.3 | 3.0 | 0.2 | 21.6 | 79.3 | 10.4 | 3.8 |
| 2010 | 2,836.6 | 3.1 | 0.2 | 22.8 | 83.6 | 10.9 | 3.1 |
| 2011 | 2,712.9 | 3.0 | 0.2 | 21.9 | 79.0 | 10.5 | 3.1 |
| 2012 | 2,918.1 | 3.0 | 0.2 | 24.2 | 79.4 | 10.7 | 3.8 |
| 2013 | 2,776.3 | 3.0 | 0.2 | 22.2 | 79.1 | 10.4 | 2.6 |
| 2014 | 3,146.5 | 3.0 | 0.2 | 25.3 | 85.0 | 11.1 | 2.8 |
| 2015 | 3,449.5 | 3.1 | 0.2 | 28.0 | 86.4 | 11.3 | 3.0 |
| 2016 | 3,649.2 | 3.1 | 0.2 | 29.1 | 87.9 | 11.5 | 3.6 |

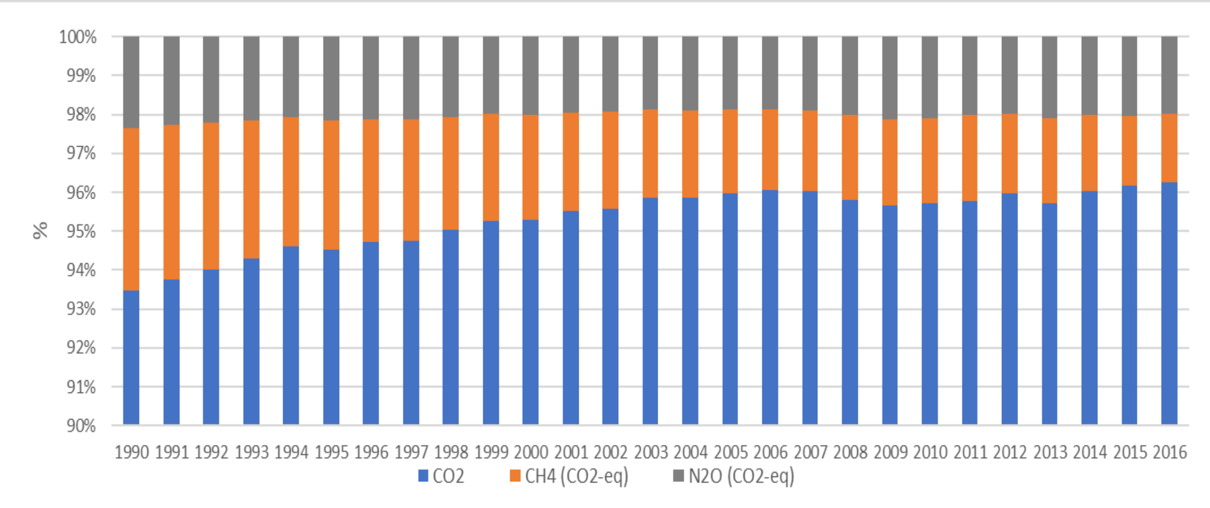


**Figure 4.2- Share of emissions by gas (%) for the Energy sector (1990 - 2016)**

### 4.5.3. Evolution of emissions by gas (Gg) in the Energy Sector (1990 - 2016)

Emissions of $CO_2$ in the Energy sector, Fuel Combustion Activities category, increased over the period 1990 to 2016, from 1,044 to 3,649 Gg. The annual increase was quite sharp up to 2007 but it stabilized thereafter until 2013 with the tendency for an increase in the last three years of the time series (Figure 4.3).

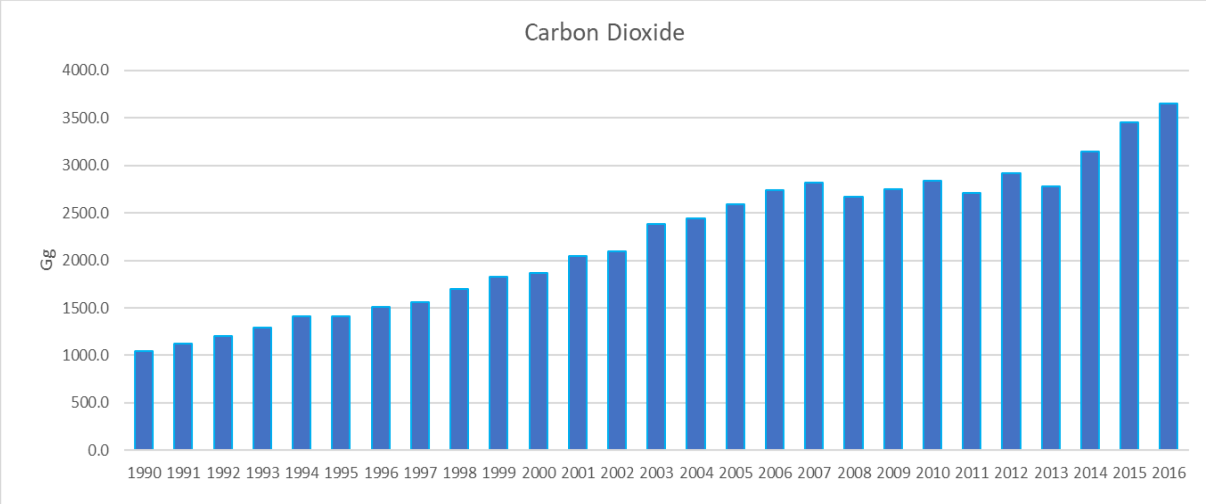


**Figure 4.3- Evolution of $CO_2$ emissions (Gg) in the Energy Sector (1990 - 2016)**

Regarding $CH_4$, emissions increased slowly from 2.2 Gg to 3.1 Gg during the period 1990 to 2016 (Figure 4.4).

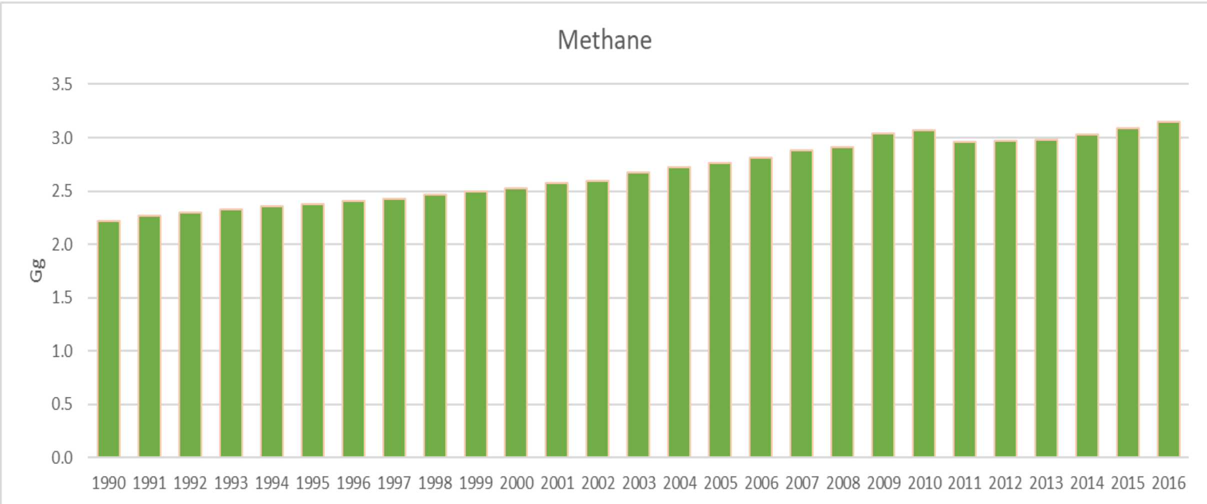


**Figure 4.4- Evolution of $CH_4$ emissions (Gg) in the Energy Sector (1990 - 2016)**

Emissions of $N_2O$ was marginal at 0.1 Gg from 1990 to 2003 and then at 0.2 Gg (Figure 4.5) from 2004 to 2016.

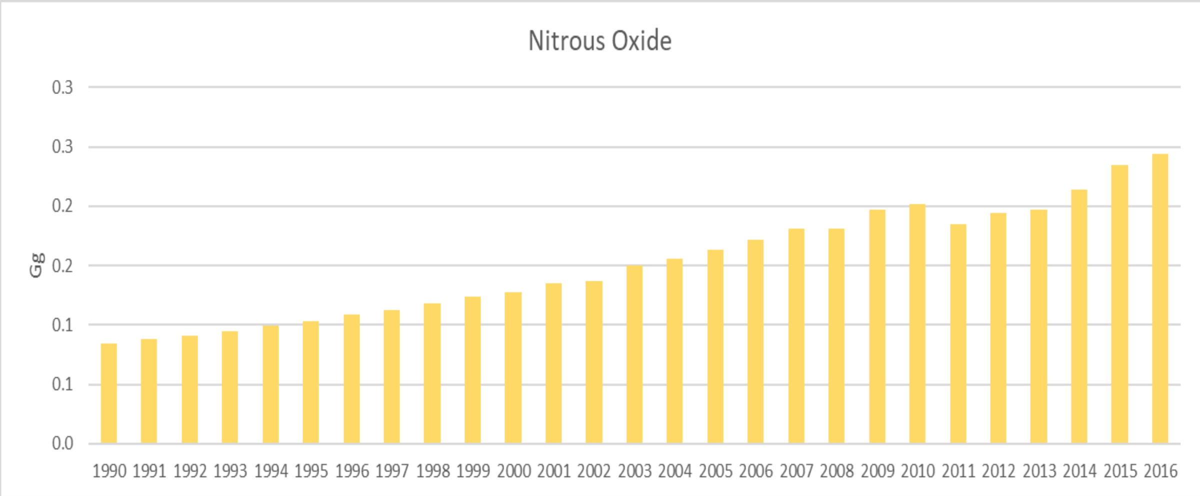


**Figure 4.5- Evolution of $N_2O$ emissions (Gg) in the Energy Sector (1990 - 2016)**

Emissions of $NO_x$ increased from 10.4 Gg to 29.1 Gg during the period 1990 to 2016 (Figure 4.6).

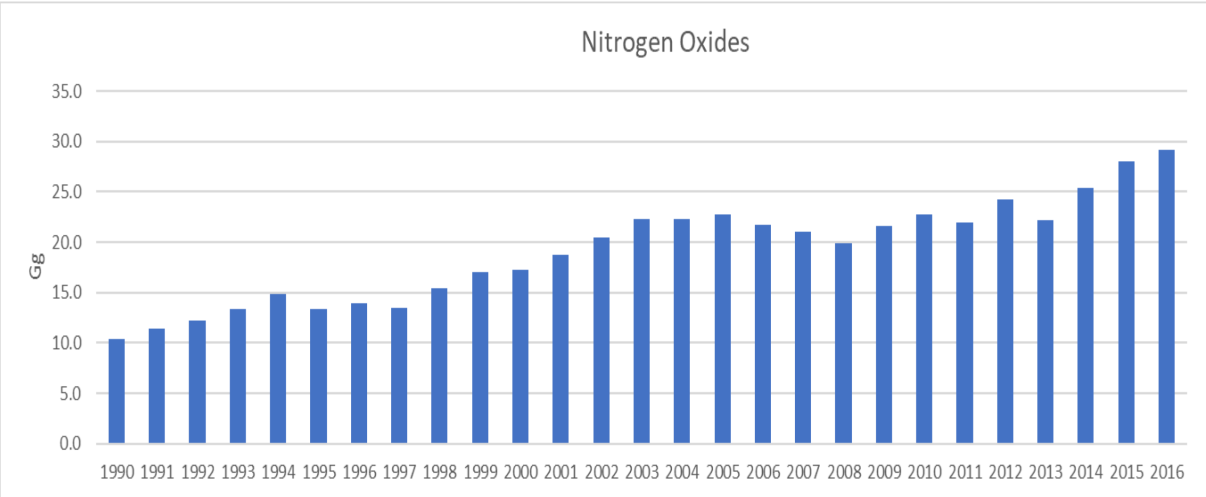


**Figure 4.6- Evolution of $NO_x$ emissions (Gg) in the Energy Sector (1990 - 2016)**

Emissions of CO increased from 46.6 Gg in 1990 to 87.9 Gg in 2016 (Figure 4.7).

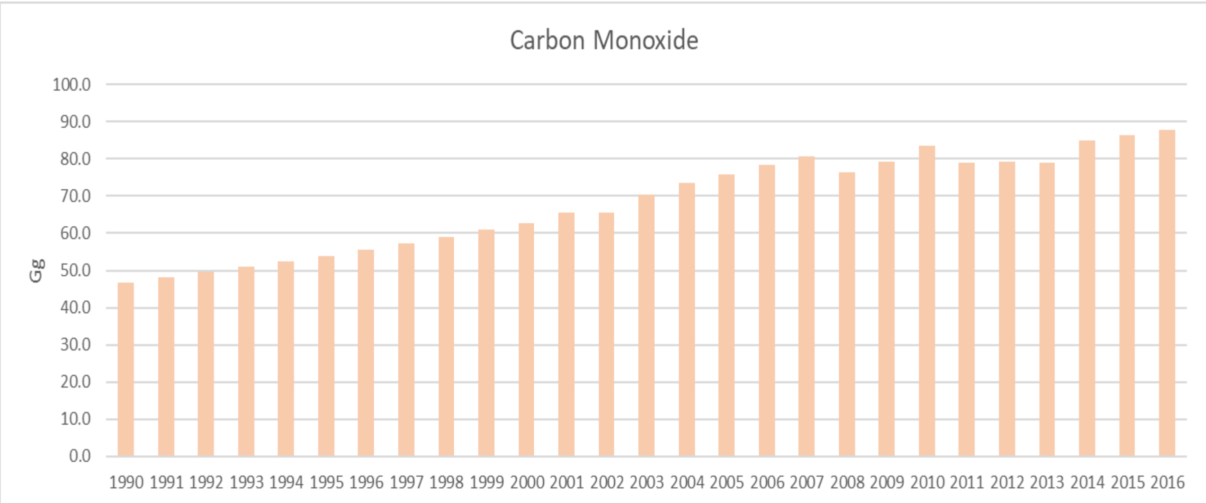


**Figure 4.7- Evolution of CO emissions (Gg) in the Energy Sector (1990 - 2016)**

NMVOCs emissions varied between 6.5 and 11.5 Gg over the inventory period 1990 to 2016 (Figure 4.8).

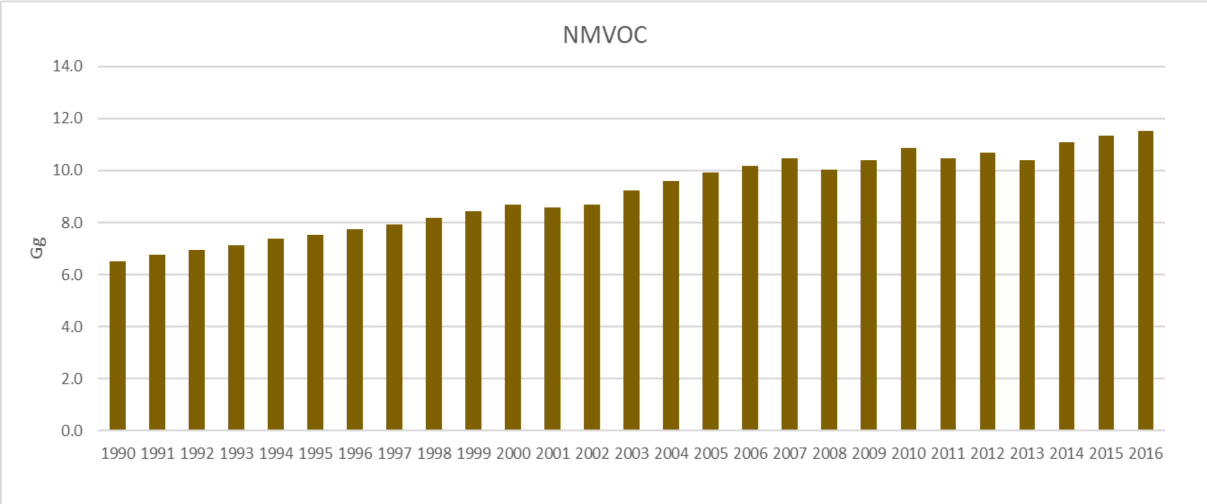


**Figure 4.8- Evolution of NMVOCs emissions (Gg) in the Energy Sector (1990 - 2016)**

$SO_2$ emissions fluctuated between 1.9 Gg and 4.3 Gg during the inventory period 1990 to 2016 with the peak in 2006 (Figure 4.9).

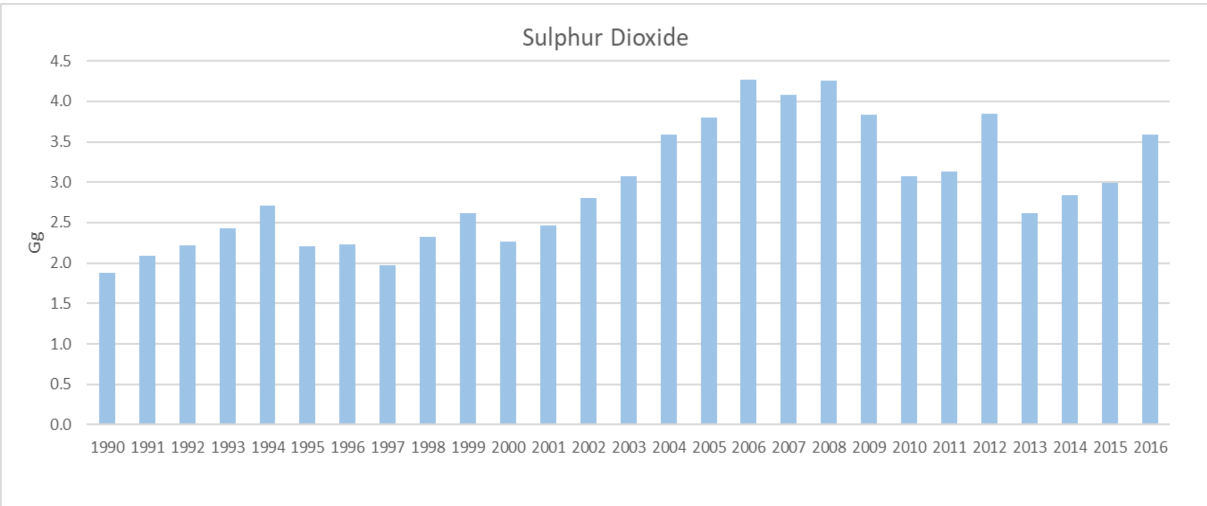


**Figure 4.9- Evolution of $SO_2$ emissions (Gg) in the Energy Sector (1990 - 2016)**

## 4.5.4. Emissions by gas by category for the period 1990 to 2016

### 4.5.4.1. $CO_2$ emissions

Emissions (Gg) of $CO_2$ for the different categories for the years 1990 to 2016 are summarized in Table 4.8. Total $CO_2$ emissions emanating from fuel combustion activities increased from 1,044 Gg in 1990 to 3,649 in 2016. For the Transport category, $CO_2$ emissions increased from 569 Gg in 1990 to 2,853 Gg in 2016, whilst for Energy Industries, it varied between 0.5 Gg to 236 Gg as the main activity electricity production only supplements imports from neighbouring countries. Emissions from the Other sectors sub-category fluctuated between 319 Gg and 541 Gg. The Non-specified sub-category emissions increased from 8 to 137 Gg over the period under review.

Table 4.8 - $CO_2$ emissions (Gg) for period 1990 - 2016

| Year | Total | Energy Industries | Manufacturing Industries and Construction | Transport | Other Sectors | Non-Specified |
|---|---|---|---|---|---|---|
| 1990 | 1,044.2 | 21.4 | 99.1 | 568.8 | 347.1 | 7.8 |
| 1991 | 1,124.9 | 23.7 | 101.9 | 614.1 | 375.9 | 9.1 |
| 1992 | 1,198.4 | 26.0 | 104.8 | 664.5 | 392.3 | 10.7 |
| 1993 | 1,295.0 | 28.3 | 107.6 | 720.8 | 425.6 | 12.6 |
| 1994 | 1,407.5 | 30.6 | 110.5 | 784.1 | 467.4 | 14.9 |
| 1995 | 1,415.1 | 32.9 | 113.4 | 866.0 | 385.0 | 17.9 |
| 1996 | 1,505.6 | 35.2 | 116.2 | 948.3 | 385.1 | 20.8 |
| 1997 | 1,555.2 | 37.5 | 119.1 | 1,030.5 | 344.3 | 23.8 |
| 1998 | 1,694.5 | 39.8 | 121.5 | 1,112.8 | 393.6 | 26.8 |
| 1999 | 1,827.3 | 42.1 | 126.2 | 1,195.0 | 434.2 | 29.8 |
| 2000 | 1,867.5 | 7.3 | 130.5 | 1,277.7 | 419.2 | 32.8 |
| 2001 | 2,045.9 | 9.2 | 141.8 | 1,408.4 | 449.6 | 36.9 |
| 2002 | 2,092.8 | 0.5 | 109.4 | 1,417.1 | 528.2 | 37.6 |
| 2003 | 2,378.9 | 21.3 | 143.3 | 1,632.0 | 541.0 | 41.3 |
| 2004 | 2,443.8 | 2.2 | 157.0 | 1,735.2 | 506.6 | 42.8 |
| 2005 | 2,590.3 | 53.6 | 145.8 | 1,853.2 | 494.7 | 43.1 |
| 2006 | 2,740.3 | 164.1 | 158.1 | 1,964.9 | 409.0 | 44.2 |
| 2007 | 2,821.7 | 195.0 | 170.0 | 2,064.5 | 348.0 | 44.2 |
| 2008 | 2,670.8 | 235.7 | 171.0 | 1,888.3 | 338.8 | 36.9 |
| 2009 | 2,748.3 | 142.6 | 180.5 | 2,015.8 | 371.1 | 38.2 |
| 2010 | 2,836.6 | 35.5 | 190.4 | 2,210.6 | 359.3 | 40.8 |
| 2011 | 2,712.9 | 13.0 | 221.0 | 2,076.0 | 358.4 | 44.5 |
| 2012 | 2,918.1 | 96.5 | 191.1 | 2,173.3 | 406.8 | 50.5 |
| 2013 | 2,776.3 | 15.4 | 174.5 | 2,215.6 | 319.0 | 51.9 |
| 2014 | 3,146.5 | 5.4 | 178.8 | 2,530.6 | 371.7 | 60.0 |
| 2015 | 3,449.5 | 20.6 | 184.8 | 2,761.9 | 375.3 | 106.9 |
| 2016 | 3,649.2 | 86.9 | 192.5 | 2,852.7 | 379.7 | 137.4 |

#### 4.5.4.2. $CH_4$ emissions

A total of 3.15 Gg of $CH_4$ was emitted from the Energy sector, Fuel Combustion Activities category in 2016 from 2.22 Gg in 1990. The main contributing sub-categories over the full period 1990 to 2016 were Other Sectors and Transport. The former emitted at 2.10 Gg and Transport with 0.63 Gg (Table 4.9) in 2016. In 2016, $CH_4$ emissions from the Energy Industries sub-category was 0.32 Gg and Manufacturing Industries and Construction emitted 0.08 Gg.

Table 4.9 - $CH_4$ emissions (Gg) (1990 - 2016)

| Year | Total | Energy Industries | Manufacturing Industries and Construction | Transport | Other Sectors | Non-Specified |
|---|---|---|---|---|---|---|
| 1990 | 2.22 | 0.14 | 0.01 | 0.20 | 1.87 | 4.1E-04 |
| 1991 | 2.27 | 0.14 | 0.01 | 0.21 | 1.91 | 4.8E-04 |
| 1992 | 2.29 | 0.14 | 0.01 | 0.22 | 1.92 | 5.7E-04 |

| Year | Total | Energy Industries | Manufacturing Industries and Construction | Transport | Other Sectors | Non-Specified |
|---|---|---|---|---|---|---|
| 1993 | 2.32 | 0.14 | 0.01 | 0.23 | 1.94 | 6.7E-04 |
| 1994 | 2.35 | 0.14 | 0.01 | 0.25 | 1.95 | 7.8E-04 |
| 1995 | 2.37 | 0.14 | 0.01 | 0.27 | 1.96 | 9.4E-04 |
| 1996 | 2.40 | 0.14 | 0.01 | 0.28 | 1.97 | 1.1E-03 |
| 1997 | 2.43 | 0.14 | 0.01 | 0.30 | 1.97 | 1.3E-03 |
| 1998 | 2.46 | 0.14 | 0.01 | 0.32 | 1.99 | 1.4E-03 |
| 1999 | 2.50 | 0.14 | 0.01 | 0.34 | 2.01 | 1.6E-03 |
| 2000 | 2.52 | 0.14 | 0.01 | 0.35 | 2.02 | 1.7E-03 |
| 2001 | 2.57 | 0.14 | 0.01 | 0.38 | 2.03 | 1.9E-03 |
| 2002 | 2.60 | 0.14 | 0.01 | 0.38 | 2.06 | 2.0E-03 |
| 2003 | 2.68 | 0.14 | 0.01 | 0.43 | 2.09 | 2.2E-03 |
| 2004 | 2.72 | 0.14 | 0.01 | 0.46 | 2.10 | 2.3E-03 |
| 2005 | 2.76 | 0.14 | 0.01 | 0.49 | 2.12 | 2.3E-03 |
| 2006 | 2.81 | 0.15 | 0.02 | 0.52 | 2.13 | 2.3E-03 |
| 2007 | 2.88 | 0.18 | 0.02 | 0.54 | 2.14 | 2.3E-03 |
| 2008 | 2.91 | 0.25 | 0.02 | 0.48 | 2.16 | 1.9E-03 |
| 2009 | 3.04 | 0.33 | 0.02 | 0.51 | 2.18 | 2.0E-03 |
| 2010 | 3.07 | 0.29 | 0.02 | 0.55 | 2.20 | 2.1E-03 |
| 2011 | 2.97 | 0.22 | 0.03 | 0.49 | 2.23 | 2.7E-03 |
| 2012 | 2.97 | 0.22 | 0.03 | 0.50 | 2.21 | 3.0E-03 |
| 2013 | 2.98 | 0.26 | 0.04 | 0.51 | 2.18 | 3.1E-03 |
| 2014 | 3.03 | 0.25 | 0.04 | 0.58 | 2.16 | 3.6E-03 |
| 2015 | 3.09 | 0.30 | 0.04 | 0.61 | 2.13 | 6.4E-03 |
| 2016 | 3.15 | 0.32 | 0.08 | 0.63 | 2.10 | 8.2E-03 |

#### 4.5.4.3. $N_2O$ emissions

Total $N_2O$ emissions from the Fuel Combustion Activities category varied from 0.09 Gg to 0.24 Gg during the period 1990 to 2016 (Table 4.10). For all years, the highest emission was from the Transport sub-category with Other Sectors and Energy Industries contributing almost equal amounts. They accounted for 0.16 Gg, 0.03 Gg and 0.04 Gg respectively in 2016. In the same year, the Manufacturing Industries and Construction sub-category emitted 0.01 Gg of $N_2O$ and Non-Specified sub-category contributed 0.008 Gg.

**Table 4.10 - $N_2O$ emissions (Gg) (1990 - 2016)**

| Year | Total | Energy Industries | Manufacturing Industries and Construction | Transport | Other Sectors | Non-Specified |
|---|---|---|---|---|---|---|
| 1990 | 0.09 | 0.02 | 0.00 | 0.04 | 0.03 | 2.7E-03 |
| 1991 | 0.09 | 0.02 | 0.00 | 0.04 | 0.03 | 2.7E-03 |
| 1992 | 0.09 | 0.02 | 0.00 | 0.04 | 0.03 | 2.9E-03 |
| 1993 | 0.10 | 0.02 | 0.00 | 0.05 | 0.03 | 3.0E-03 |
| 1994 | 0.10 | 0.02 | 0.00 | 0.05 | 0.03 | 3.2E-03 |
| 1995 | 0.11 | 0.02 | 0.00 | 0.05 | 0.03 | 3.4E-03 |
| 1996 | 0.11 | 0.02 | 0.00 | 0.06 | 0.03 | 3.6E-03 |

| Year | Total | Energy Industries | Manufacturing Industries and Construction | Transport | Other Sectors | Non-Specified |
|---|---|---|---|---|---|---|
| 1997 | 0.12 | 0.02 | 0.00 | 0.06 | 0.03 | 3.8E-03 |
| 1998 | 0.12 | 0.02 | 0.00 | 0.07 | 0.03 | 4.0E-03 |
| 1999 | 0.13 | 0.02 | 0.00 | 0.07 | 0.03 | 4.2E-03 |
| 2000 | 0.13 | 0.02 | 0.00 | 0.08 | 0.03 | 4.4E-03 |
| 2001 | 0.14 | 0.02 | 0.00 | 0.08 | 0.03 | 4.6E-03 |
| 2002 | 0.14 | 0.02 | 0.00 | 0.08 | 0.03 | 4.8E-03 |
| 2003 | 0.15 | 0.02 | 0.00 | 0.10 | 0.03 | 5.0E-03 |
| 2004 | 0.16 | 0.02 | 0.00 | 0.10 | 0.03 | 5.3E-03 |
| 2005 | 0.17 | 0.02 | 0.00 | 0.11 | 0.03 | 5.5E-03 |
| 2006 | 0.18 | 0.02 | 0.00 | 0.11 | 0.03 | 5.7E-03 |
| 2007 | 0.18 | 0.03 | 0.00 | 0.12 | 0.03 | 5.9E-03 |
| 2008 | 0.19 | 0.04 | 0.00 | 0.11 | 0.03 | 6.1E-03 |
| 2009 | 0.20 | 0.05 | 0.00 | 0.12 | 0.03 | 6.4E-03 |
| 2010 | 0.21 | 0.04 | 0.00 | 0.13 | 0.03 | 6.6E-03 |
| 2011 | 0.19 | 0.03 | 0.00 | 0.12 | 0.03 | 6.8E-03 |
| 2012 | 0.20 | 0.03 | 0.00 | 0.12 | 0.03 | 7.1E-03 |
| 2013 | 0.20 | 0.03 | 0.01 | 0.12 | 0.03 | 7.4E-03 |
| 2014 | 0.22 | 0.03 | 0.01 | 0.14 | 0.03 | 7.6E-03 |
| 2015 | 0.24 | 0.04 | 0.01 | 0.15 | 0.03 | 7.9E-03 |
| 2016 | 0.24 | 0.04 | 0.01 | 0.16 | 0.03 | 7.9E-03 |

#### 4.5.4.4. $NO_x$ emissions

Emissions of $NO_x$ from the combustion of fuels increased from 10.4 Gg in 1990 to 29.1 Gg in 2016. The main contributor was the Transport and Other Sectors sub-categories. Energy Industries, Manufacturing Industries and Construction, and Non-Specified sub-categories (Table 4.11) contributed much lesser amounts. Transport emissions increased from 3.1 Gg in 1990 to 19.0 in 2016. Emissions from the Other Sectors sub-category varied between 5.9 Gg and 11.0 Gg during the period 1990 to 2016 while Energy Industries emissions fluctuated between 0.39 Gg to 1.06 Gg. Non-Specified sub-category emissions increased from 0.08 in 1990 to 1.43 Gg in 2016.

**Table 4.11 - $NO_x$ emissions (Gg) (1990 - 2016)**

| Year | Total | Energy Industries | Manufacturing Industries and Construction | Transport | Other Sectors | Non-Specified |
|---|---|---|---|---|---|---|
| 1990 | 10.4 | 0.43 | 0.32 | 3.1 | 6.5 | 0.08 |
| 1991 | 11.5 | 0.43 | 0.34 | 3.4 | 7.2 | 0.10 |
| 1992 | 12.2 | 0.44 | 0.35 | 3.7 | 7.6 | 0.11 |
| 1993 | 13.4 | 0.44 | 0.37 | 4.1 | 8.4 | 0.13 |
| 1994 | 14.9 | 0.45 | 0.39 | 4.5 | 9.4 | 0.16 |
| 1995 | 13.4 | 0.45 | 0.40 | 5.0 | 7.3 | 0.19 |
| 1996 | 14.0 | 0.46 | 0.42 | 5.6 | 7.3 | 0.22 |
| 1997 | 13.5 | 0.46 | 0.43 | 6.2 | 6.2 | 0.25 |
| 1998 | 15.4 | 0.47 | 0.45 | 6.7 | 7.5 | 0.28 |
| 1999 | 17.0 | 0.47 | 0.47 | 7.3 | 8.5 | 0.31 |
| 2000 | 17.3 | 0.40 | 0.48 | 7.8 | 8.3 | 0.34 |

| Year | Total | Energy Industries | Manufacturing Industries and Construction | Transport | Other Sectors | Non-Specified |
|---|---|---|---|---|---|---|
| 2001 | 18.7 | 0.40 | 0.32 | 8.6 | 9.0 | 0.39 |
| 2002 | 20.5 | 0.38 | 0.32 | 8.8 | 10.7 | 0.39 |
| 2003 | 22.3 | 0.43 | 0.34 | 10.1 | 11.0 | 0.43 |
| 2004 | 22.3 | 0.39 | 0.58 | 10.8 | 10.1 | 0.45 |
| 2005 | 22.7 | 0.49 | 0.56 | 11.5 | 9.7 | 0.45 |
| 2006 | 21.7 | 0.76 | 0.63 | 12.1 | 7.8 | 0.46 |
| 2007 | 21.1 | 0.90 | 0.73 | 12.7 | 6.3 | 0.46 |
| 2008 | 19.9 | 1.18 | 0.77 | 11.8 | 5.8 | 0.39 |
| 2009 | 21.6 | 1.19 | 0.74 | 12.7 | 6.6 | 0.40 |
| 2010 | 22.8 | 0.86 | 0.76 | 13.9 | 6.8 | 0.43 |
| 2011 | 21.9 | 0.62 | 0.79 | 13.4 | 6.7 | 0.46 |
| 2012 | 24.2 | 0.80 | 0.79 | 14.1 | 8.0 | 0.52 |
| 2013 | 22.2 | 0.73 | 0.67 | 14.3 | 5.9 | 0.54 |
| 2014 | 25.3 | 0.69 | 0.67 | 16.3 | 7.0 | 0.62 |
| 2015 | 28.0 | 0.86 | 0.70 | 18.4 | 6.9 | 1.11 |
| 2016 | 29.1 | 1.06 | 0.74 | 19.0 | 6.9 | 1.43 |

#### 4.5.4.5. CO emissions

The Energy sector Fuel Combustion Activities category CO emissions of 46.6 Gg in 1990 increased to 87.9 Gg in 2016. The emissions originated mainly from the Transport and Other Sectors sub-categories with 54.2 Gg and 30.8 Gg respectively in 2016 (Table 4.12). CO emissions for the Manufacturing Industries and Construction increased from 0.10 Gg in 1990 to 1.44 Gg in 2016 while Non-Specified sub-category emissions evolved from 0.02 Gg in 1990 to 0.44 Gg in 2016. Emissions from Energy Industries were marginal at less than 1 Gg throughout the time series.

**Table 4.12 - CO emissions (Gg) (1990 – 2016)**

| Year | Total | Energy Industries | Manufacturing Industries and Construction | Transport | Other Sectors | Non-Specified |
|---|---|---|---|---|---|---|
| 1990 | 46.6 | 4.2E-01 | 0.10 | 19.89 | 26.17 | 0.02 |
| 1991 | 48.2 | 4.2E-01 | 0.10 | 20.86 | 26.80 | 0.02 |
| 1992 | 49.5 | 4.2E-01 | 0.11 | 21.88 | 27.09 | 0.03 |
| 1993 | 50.9 | 4.2E-01 | 0.11 | 22.96 | 27.42 | 0.03 |
| 1994 | 52.4 | 4.2E-01 | 0.11 | 24.10 | 27.77 | 0.04 |
| 1995 | 54.0 | 4.2E-01 | 0.12 | 25.55 | 27.82 | 0.04 |
| 1996 | 55.7 | 4.2E-01 | 0.12 | 27.00 | 28.07 | 0.05 |
| 1997 | 57.3 | 4.2E-01 | 0.12 | 28.46 | 28.22 | 0.06 |
| 1998 | 59.1 | 4.2E-01 | 0.12 | 29.91 | 28.59 | 0.06 |
| 1999 | 60.9 | 4.3E-01 | 0.13 | 31.36 | 28.94 | 0.07 |
| 2000 | 62.8 | 4.2E-01 | 0.13 | 32.89 | 29.26 | 0.08 |
| 2001 | 65.5 | 4.2E-01 | 0.05 | 35.39 | 29.51 | 0.09 |
| 2002 | 65.7 | 4.2E-01 | 0.05 | 35.07 | 30.03 | 0.09 |
| 2003 | 70.4 | 4.2E-01 | 0.07 | 39.35 | 30.43 | 0.10 |
| 2004 | 73.5 | 4.2E-01 | 1.01 | 41.25 | 30.71 | 0.10 |
| 2005 | 75.9 | 4.2E-01 | 0.91 | 43.45 | 31.04 | 0.10 |

| Year | Total | Energy Industries | Manufacturing Industries and Construction | Transport | Other Sectors | Non-Specified |
|---|---|---|---|---|---|---|
| 2006 | 78.5 | 4.7E-01 | 0.93 | 45.76 | 31.22 | 0.11 |
| 2007 | 80.6 | 5.4E-01 | 0.89 | 47.57 | 31.45 | 0.11 |
| 2008 | 76.5 | 7.6E-01 | 0.83 | 43.07 | 31.77 | 0.09 |
| 2009 | 79.3 | 9.9E-01 | 1.00 | 44.99 | 32.22 | 0.09 |
| 2010 | 83.6 | 8.8E-01 | 1.10 | 48.91 | 32.61 | 0.10 |
| 2011 | 79.0 | 6.6E-01 | 1.43 | 43.74 | 33.07 | 0.14 |
| 2012 | 79.4 | 6.7E-01 | 1.36 | 44.24 | 32.96 | 0.16 |
| 2013 | 79.1 | 7.7E-01 | 1.38 | 45.16 | 31.59 | 0.16 |
| 2014 | 85.0 | 7.6E-01 | 1.39 | 51.21 | 31.43 | 0.19 |
| 2015 | 86.4 | 9.1E-01 | 1.42 | 52.64 | 31.14 | 0.34 |
| 2016 | 87.9 | 9.7E-01 | 1.44 | 54.24 | 30.84 | 0.44 |

#### 4.5.4.6. NMVOC emissions

Total NMVOC emissions increased from 6.5 Gg in 1990 to 11.5 Gg in 2016. NMVOCs originated mainly from the Transport and Other Sectors sub-categories and they accounted for 5.8 Gg and 5.2 Gg of emissions of the Energy sector respectively in 2016 (Table 4.13). The other three sub-categories contributed marginally to total NMVOC emission with 0.53 Gg combined.

**Table 4.13 - NMVOCs emissions (Gg) (1990 - 2016)**

| Year | Total | Energy Industries | Manufacturing Industries and Construction | Transport | Other Sectors | Non-Specified |
|---|---|---|---|---|---|---|
| 1990 | 6.51 | 0.03 | 0.40 | 1.85 | 4.23 | 0.00 |
| 1991 | 6.75 | 0.03 | 0.40 | 1.96 | 4.35 | 0.01 |
| 1992 | 6.93 | 0.03 | 0.41 | 2.07 | 4.42 | 0.01 |
| 1993 | 7.14 | 0.03 | 0.41 | 2.18 | 4.50 | 0.01 |
| 1994 | 7.36 | 0.03 | 0.42 | 2.31 | 4.59 | 0.01 |
| 1995 | 7.51 | 0.03 | 0.42 | 2.47 | 4.57 | 0.01 |
| 1996 | 7.73 | 0.03 | 0.43 | 2.63 | 4.63 | 0.01 |
| 1997 | 7.92 | 0.03 | 0.43 | 2.80 | 4.64 | 0.01 |
| 1998 | 8.18 | 0.03 | 0.44 | 2.96 | 4.74 | 0.02 |
| 1999 | 8.44 | 0.03 | 0.44 | 3.12 | 4.83 | 0.02 |
| 2000 | 8.70 | 0.03 | 0.47 | 3.28 | 4.91 | 0.02 |
| 2001 | 8.57 | 0.03 | 0.02 | 3.56 | 4.94 | 0.02 |
| 2002 | 8.68 | 0.03 | 0.02 | 3.53 | 5.07 | 0.02 |
| 2003 | 9.25 | 0.03 | 0.03 | 4.01 | 5.15 | 0.02 |
| 2004 | 9.61 | 0.03 | 0.13 | 4.23 | 5.19 | 0.03 |
| 2005 | 9.92 | 0.03 | 0.13 | 4.48 | 5.25 | 0.03 |
| 2006 | 10.20 | 0.04 | 0.14 | 4.74 | 5.25 | 0.03 |
| 2007 | 10.45 | 0.04 | 0.16 | 4.95 | 5.27 | 0.03 |
| 2008 | 10.04 | 0.06 | 0.18 | 4.46 | 5.32 | 0.02 |
| 2009 | 10.40 | 0.08 | 0.19 | 4.69 | 5.42 | 0.02 |
| 2010 | 10.88 | 0.07 | 0.19 | 5.09 | 5.50 | 0.02 |
| 2011 | 10.45 | 0.05 | 0.23 | 4.56 | 5.58 | 0.03 |

| Year | Total | Energy Industries | Manufacturing Industries and Construction | Transport | Other Sectors | Non-Specified |
|---|---|---|---|---|---|---|
| 2012 | 10.67 | 0.06 | 0.33 | 4.64 | 5.61 | 0.03 |
| 2013 | 10.39 | 0.06 | 0.34 | 4.74 | 5.22 | 0.03 |
| 2014 | 11.09 | 0.06 | 0.34 | 5.41 | 5.23 | 0.04 |
| 2015 | 11.34 | 0.07 | 0.35 | 5.64 | 5.20 | 0.07 |
| 2016 | 11.51 | 0.08 | 0.36 | 5.81 | 5.17 | 0.09 |

#### 4.5.4.7. $SO_2$ emissions

Total $SO_2$ emissions in the Energy sector varied between 1.9 Gg and 4.3 Gg for the time series 1990 to 2016. Emissions of $SO_2$ across the time period were more important in the Other Sectors sub-category followed by the Manufacturing Industries and Construction sub-category (Table 4.14). Emissions in the former sub-category varied between 1.5 Gg and 2.8 Gg while in the Manufacturing and Construction sub-category, the emissions increased from 0.02 Gg in 1990 to 0.92 Gg in 2016 after a peak of 1.21 Gg in 2011.

**Table 4.14 - $SO_2$ emissions (Gg) (1990 - 2016)**

| Year | Total | Energy Industries | Manufacturing Industries and Construction | Transport | Other Sectors | Non-Specified |
|---|---|---|---|---|---|---|
| 1990 | 1.9 | 0.23 | 0.02 | 0.01 | 1.6 | 3.9E-05 |
| 1991 | 2.1 | 0.25 | 0.02 | 0.01 | 1.8 | 4.6E-05 |
| 1992 | 2.2 | 0.27 | 0.02 | 0.01 | 1.9 | 5.4E-05 |
| 1993 | 2.4 | 0.29 | 0.02 | 0.01 | 2.1 | 6.3E-05 |
| 1994 | 2.7 | 0.31 | 0.02 | 0.01 | 2.4 | 7.5E-05 |
| 1995 | 2.2 | 0.33 | 0.02 | 0.01 | 1.8 | 9.0E-05 |
| 1996 | 2.2 | 0.35 | 0.03 | 0.01 | 1.8 | 1.0E-04 |
| 1997 | 2.0 | 0.37 | 0.03 | 0.01 | 1.6 | 1.2E-04 |
| 1998 | 2.3 | 0.39 | 0.03 | 0.01 | 1.9 | 1.3E-04 |
| 1999 | 2.6 | 0.41 | 0.03 | 0.02 | 2.2 | 1.5E-04 |
| 2000 | 2.3 | 0.11 | 0.03 | 0.02 | 2.1 | 1.6E-04 |
| 2001 | 2.5 | 0.13 | 0.03 | 0.02 | 2.3 | 1.9E-04 |
| 2002 | 2.8 | 0.05 | 0.03 | 0.02 | 2.7 | 1.9E-04 |
| 2003 | 3.1 | 0.23 | 0.03 | 0.02 | 2.8 | 2.1E-04 |
| 2004 | 3.6 | 0.07 | 0.92 | 0.02 | 2.6 | 2.2E-04 |
| 2005 | 3.8 | 0.51 | 0.79 | 0.02 | 2.5 | 2.2E-04 |
| 2006 | 4.3 | 1.46 | 0.81 | 0.02 | 2.0 | 2.2E-04 |
| 2007 | 4.1 | 1.73 | 0.72 | 0.02 | 1.6 | 2.2E-04 |
| 2008 | 4.3 | 2.13 | 0.62 | 0.02 | 1.5 | 1.9E-04 |
| 2009 | 3.8 | 1.35 | 0.78 | 0.02 | 1.7 | 1.9E-04 |
| 2010 | 3.1 | 0.40 | 0.89 | 0.02 | 1.8 | 2.0E-04 |
| 2011 | 3.1 | 0.18 | 1.21 | 0.02 | 1.7 | 2.3E-04 |
| 2012 | 3.8 | 0.88 | 0.90 | 0.02 | 2.0 | 2.6E-04 |
| 2013 | 2.6 | 0.21 | 0.90 | 0.02 | 1.5 | 2.7E-04 |
| 2014 | 2.8 | 0.13 | 0.90 | 0.03 | 1.8 | 3.1E-04 |
| 2015 | 3.0 | 0.29 | 0.91 | 0.03 | 1.8 | 5.5E-04 |

| Year | Total | Energy Industries | Manufacturing Industries and Construction | Transport | Other Sectors | Non-Specified |
|---|---|---|---|---|---|---|
| 2016 | 3.6 | 0.87 | 0.92 | 0.03 | 1.8 | 7.1E-04 |

### 4.5.5. Memo Items

***International Bunkering***

Both international aviation and Navigation were covered in this inventory for the full time series. As expected, emissions increased over the period 1990 to 2016 due to enhanced levels of activities in both seaports and airports.

Total emissions from international bunkers are given in Table 4.15. They increased by 27% from 209 Gg $CO_2$-eq in the year 1990 to 266 Gg $CO_2$-eq in 2016. $CO_2$ was the major contributor with slightly more than 99% of total bunkering emissions for all the years. The other direct gases $CH_4$ and $N_2O$ contributed the remainder.

**Table 4.15 - Total emissions (Gg $CO_2$-eq) and by gas (Gg) from international bunkers (1990 - 2016)**

| Year | Total ($CO_2$-eq) | $CO_2$ ($CO_2$-eq) | $CH_4$ ($CO_2$-eq) | $N_2O$ ($CO_2$-eq) | $NO_x$ (Gg) | CO (Gg) | NMVOCs (Gg) | $SO_2$ (Gg) |
|---|---|---|---|---|---|---|---|---|
| 1990 | 209.17 | 207.15 | 0.014 | 0.006 | 3.80 | 0.614 | 0.21 | 0.638 |
| 1991 | 209.94 | 207.91 | 0.014 | 0.006 | 3.78 | 0.606 | 0.21 | 0.629 |
| 1992 | 210.71 | 208.67 | 0.014 | 0.006 | 3.76 | 0.600 | 0.21 | 0.619 |
| 1993 | 211.49 | 209.44 | 0.014 | 0.006 | 3.74 | 0.594 | 0.20 | 0.610 |
| 1994 | 212.27 | 210.22 | 0.014 | 0.006 | 3.72 | 0.588 | 0.20 | 0.600 |
| 1995 | 213.05 | 211.00 | 0.013 | 0.006 | 3.70 | 0.582 | 0.20 | 0.591 |
| 1996 | 213.84 | 211.78 | 0.013 | 0.006 | 3.68 | 0.577 | 0.20 | 0.581 |
| 1997 | 214.63 | 212.57 | 0.013 | 0.006 | 3.66 | 0.571 | 0.20 | 0.572 |
| 1998 | 215.43 | 213.36 | 0.013 | 0.006 | 3.64 | 0.565 | 0.19 | 0.562 |
| 1999 | 216.24 | 214.16 | 0.013 | 0.006 | 3.63 | 0.559 | 0.19 | 0.553 |
| 2000 | 222.25 | 220.13 | 0.013 | 0.006 | 3.63 | 0.555 | 0.19 | 0.544 |
| 2001 | 225.11 | 222.96 | 0.013 | 0.006 | 2.30 | 0.556 | 0.19 | 0.533 |
| 2002 | 227.80 | 225.62 | 0.013 | 0.006 | 2.25 | 0.556 | 0.19 | 0.521 |
| 2003 | 230.49 | 228.29 | 0.013 | 0.006 | 2.21 | 0.556 | 0.19 | 0.509 |
| 2004 | 233.20 | 230.97 | 0.014 | 0.006 | 3.83 | 0.712 | 0.25 | 0.917 |
| 2005 | 235.90 | 233.65 | 0.014 | 0.006 | 3.88 | 0.721 | 0.25 | 0.929 |
| 2006 | 238.61 | 236.34 | 0.014 | 0.006 | 3.93 | 0.731 | 0.25 | 0.941 |
| 2007 | 241.33 | 239.04 | 0.014 | 0.006 | 3.98 | 0.740 | 0.26 | 0.952 |
| 2008 | 244.07 | 241.74 | 0.014 | 0.007 | 4.03 | 0.749 | 0.26 | 0.964 |
| 2009 | 246.81 | 244.46 | 0.014 | 0.007 | 4.08 | 0.758 | 0.26 | 0.976 |
| 2010 | 251.30 | 248.91 | 0.015 | 0.007 | 4.13 | 0.768 | 0.27 | 0.989 |
| 2011 | 276.30 | 273.68 | 0.015 | 0.007 | 4.31 | 0.793 | 0.28 | 1.019 |
| 2012 | 265.63 | 263.11 | 0.015 | 0.007 | 4.27 | 0.789 | 0.27 | 1.015 |
| 2013 | 265.63 | 263.11 | 0.015 | 0.007 | 4.27 | 0.789 | 0.27 | 1.015 |
| 2014 | 265.63 | 263.11 | 0.015 | 0.007 | 4.27 | 0.789 | 0.27 | 1.015 |
| 2015 | 265.63 | 263.11 | 0.015 | 0.007 | 4.27 | 0.789 | 0.27 | 1.015 |
| 2016 | 265.63 | 263.11 | 0.015 | 0.007 | 4.27 | 0.789 | 0.27 | 1.015 |

Total emissions from international aviation increased from 63.5 Gg $CO_2$-eq to 109.7 Gg $CO_2$-eq (Table 4.16), representing an increase of 73% in 2016 over the 1990 emissions. Once more, $CO_2$ constituted more than 99% of the aggregated emissions of the direct gases.

**Table 4.16 - Total emissions (Gg $CO_2$-eq) and by gas (Gg) from international aviation (1990 - 2016)**

| Year | Total ($CO_2$-eq) | $CO_2$ ($CO_2$-eq) | $CH_4$ ($CO_2$-eq) | $N_2O$ ($CO_2$-eq) | $NO_x$ (Gg) | CO (Gg) | NMVOCs (Gg) | $SO_2$ (Gg) |
|---|---|---|---|---|---|---|---|---|
| 1990 | 63.5 | 62.9 | 0.000 | 0.002 | 0.255 | 0.022 | 0.010 | 0.020 |
| 1991 | 65.4 | 64.8 | 0.000 | 0.002 | 0.263 | 0.023 | 0.010 | 0.021 |
| 1992 | 67.3 | 66.7 | 0.000 | 0.002 | 0.271 | 0.023 | 0.011 | 0.021 |
| 1993 | 69.2 | 68.6 | 0.000 | 0.002 | 0.279 | 0.024 | 0.011 | 0.022 |
| 1994 | 71.2 | 70.5 | 0.000 | 0.002 | 0.286 | 0.025 | 0.011 | 0.022 |
| 1995 | 73.1 | 72.4 | 0.001 | 0.002 | 0.294 | 0.025 | 0.011 | 0.023 |
| 1996 | 75.0 | 74.3 | 0.001 | 0.002 | 0.302 | 0.026 | 0.012 | 0.024 |
| 1997 | 76.9 | 76.2 | 0.001 | 0.002 | 0.310 | 0.027 | 0.012 | 0.024 |
| 1998 | 78.8 | 78.2 | 0.001 | 0.002 | 0.317 | 0.027 | 0.012 | 0.025 |
| 1999 | 80.8 | 80.1 | 0.001 | 0.002 | 0.325 | 0.028 | 0.013 | 0.025 |
| 2000 | 88.0 | 87.2 | 0.001 | 0.002 | 0.354 | 0.030 | 0.014 | 0.028 |
| 2001 | 88.9 | 88.1 | 0.001 | 0.002 | 0.358 | 0.031 | 0.014 | 0.028 |
| 2002 | 89.8 | 89.0 | 0.001 | 0.002 | 0.361 | 0.031 | 0.014 | 0.028 |
| 2003 | 90.7 | 89.9 | 0.001 | 0.003 | 0.365 | 0.031 | 0.014 | 0.029 |
| 2004 | 91.6 | 90.8 | 0.001 | 0.003 | 0.369 | 0.032 | 0.014 | 0.029 |
| 2005 | 92.5 | 91.7 | 0.001 | 0.003 | 0.372 | 0.032 | 0.015 | 0.029 |
| 2006 | 93.5 | 92.6 | 0.001 | 0.003 | 0.376 | 0.032 | 0.015 | 0.029 |
| 2007 | 94.4 | 93.6 | 0.001 | 0.003 | 0.380 | 0.033 | 0.015 | 0.030 |
| 2008 | 95.3 | 94.5 | 0.001 | 0.003 | 0.384 | 0.033 | 0.015 | 0.030 |
| 2009 | 96.3 | 95.4 | 0.001 | 0.003 | 0.387 | 0.033 | 0.015 | 0.030 |
| 2010 | 99.0 | 98.1 | 0.001 | 0.003 | 0.398 | 0.034 | 0.016 | 0.031 |
| 2011 | 120.3 | 119.3 | 0.001 | 0.003 | 0.484 | 0.042 | 0.019 | 0.038 |
| 2012 | 109.7 | 108.7 | 0.001 | 0.003 | 0.441 | 0.038 | 0.017 | 0.034 |
| 2013 | 109.7 | 108.7 | 0.001 | 0.003 | 0.441 | 0.038 | 0.017 | 0.034 |
| 2014 | 109.7 | 108.7 | 0.001 | 0.003 | 0.441 | 0.038 | 0.017 | 0.034 |
| 2015 | 109.7 | 108.7 | 0.001 | 0.003 | 0.441 | 0.038 | 0.017 | 0.034 |
| 2016 | 109.7 | 108.7 | 0.001 | 0.003 | 0.441 | 0.038 | 0.017 | 0.034 |

International water-borne navigation was responsible for more emissions compared to aviation bunkering. $CO_2$ exceeded by far the emissions of $CH_4$ and $N_2O$ combined with more than 99% throughout the time series. Total aggregated emissions of the direct gases increased by 7% from 146 Gg $CO_2$-eq in 1990 to 156 Gg $CO_2$-eq in 2016 (Table 4.17).

**Table 4.17 - Total emissions (Gg $CO_2$-eq) and by gas (Gg) from international water-borne navigation (1990 - 2016)**

| Year | Total ($CO_2$-eq) | $CO_2$ ($CO_2$-eq) | $CH_4$ ($CO_2$-eq) | $N_2O$ ($CO_2$-eq) | $NO_x$ (Gg) | CO (Gg) | NMVOCs (Gg) | $SO_2$ (Gg) |
|---|---|---|---|---|---|---|---|---|
| 1990 | 145.7 | 144.2 | 0.013 | 0.004 | 3.545 | 0.592 | 0.201 | 0.618 |
| 1991 | 144.6 | 143.1 | 0.013 | 0.004 | 3.517 | 0.583 | 0.198 | 0.608 |
| 1992 | 143.4 | 142.0 | 0.013 | 0.004 | 3.490 | 0.577 | 0.196 | 0.598 |

| Year | Total ($CO_2$-eq) | $CO_2$ ($CO_2$-eq) | $CH_4$ ($CO_2$-eq) | $N_2O$ ($CO_2$-eq) | $NO_x$ (Gg) | CO (Gg) | NMVOCs (Gg) | $SO_2$ (Gg) |
|---|---|---|---|---|---|---|---|---|
| 1993 | 142.3 | 140.8 | 0.013 | 0.004 | 3.462 | 0.570 | 0.194 | 0.588 |
| 1994 | 141.1 | 139.7 | 0.013 | 0.004 | 3.435 | 0.564 | 0.191 | 0.578 |
| 1995 | 140.0 | 138.6 | 0.013 | 0.004 | 3.408 | 0.557 | 0.189 | 0.568 |
| 1996 | 138.8 | 137.4 | 0.013 | 0.004 | 3.381 | 0.551 | 0.187 | 0.558 |
| 1997 | 137.7 | 136.3 | 0.013 | 0.004 | 3.354 | 0.544 | 0.184 | 0.548 |
| 1998 | 136.6 | 135.2 | 0.013 | 0.004 | 3.327 | 0.538 | 0.182 | 0.538 |
| 1999 | 135.5 | 134.1 | 0.012 | 0.004 | 3.301 | 0.531 | 0.180 | 0.527 |
| 2000 | 134.2 | 132.9 | 0.012 | 0.004 | 3.272 | 0.524 | 0.177 | 0.517 |
| 2001 | 136.2 | 134.9 | 0.013 | 0.004 | 1.942 | 0.525 | 0.177 | 0.505 |
| 2002 | 138.0 | 136.6 | 0.013 | 0.004 | 1.893 | 0.525 | 0.177 | 0.493 |
| 2003 | 139.8 | 138.4 | 0.013 | 0.004 | 1.843 | 0.525 | 0.177 | 0.480 |
| 2004 | 141.6 | 140.2 | 0.013 | 0.004 | 3.460 | 0.680 | 0.233 | 0.888 |
| 2005 | 143.4 | 141.9 | 0.013 | 0.004 | 3.505 | 0.689 | 0.236 | 0.900 |
| 2006 | 145.2 | 143.7 | 0.013 | 0.004 | 3.551 | 0.698 | 0.239 | 0.911 |
| 2007 | 146.9 | 145.5 | 0.013 | 0.004 | 3.597 | 0.707 | 0.242 | 0.923 |
| 2008 | 148.7 | 147.2 | 0.014 | 0.004 | 3.643 | 0.716 | 0.245 | 0.934 |
| 2009 | 150.5 | 149.0 | 0.014 | 0.004 | 3.689 | 0.725 | 0.248 | 0.946 |
| 2010 | 152.3 | 150.8 | 0.014 | 0.004 | 3.734 | 0.734 | 0.251 | 0.957 |
| 2011 | 156.0 | 154.4 | 0.014 | 0.004 | 3.825 | 0.751 | 0.257 | 0.981 |
| 2012 | 156.0 | 154.4 | 0.014 | 0.004 | 3.825 | 0.751 | 0.257 | 0.981 |
| 2013 | 156.0 | 154.4 | 0.014 | 0.004 | 3.825 | 0.751 | 0.257 | 0.981 |
| 2014 | 156.0 | 154.4 | 0.014 | 0.004 | 3.825 | 0.751 | 0.257 | 0.981 |
| 2015 | 156.0 | 154.4 | 0.014 | 0.004 | 3.825 | 0.751 | 0.257 | 0.981 |
| 2016 | 156.0 | 154.4 | 0.014 | 0.004 | 3.825 | 0.751 | 0.257 | 0.981 |

### 4.5.6. Information items

#### *$CO_2$ from Biomass Combustion for Energy Production*

The evolution of $CO_2$ emissions (Gg) from biomass burning for energy production is given in Table 4.18. Emissions increased by 66% from 1,215 Gg in 1990 to 2,017 in 2016.

**Table 4.18 - Emissions of $CO_2$ (Gg) from Biomass Combustion for Energy Production (1990 - 2010)**

| Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ | 1,215 | 1,229 | 1,233 | 1,237 | 1,242 | 1,246 | 1,250 | 1,255 | 1,259 | 1,263 | 1,268 | 1,272 | 1,279 | 1,287 |

| Year | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ | 1,296 | 1,292 | 1,346 | 1,447 | 1,716 | 2,019 | 1,901 | 1,640 | 1,688 | 1,821 | 1,791 | 1,963 | 2,017 |

## Table 4.19 - Sectoral Table Energy sector (Inventory Year: 2016)

| Categories | Emissions (Gg) | | | | | | |
|---|---|---|---|---|---|---|---|
| | CO2 | CH4 | N2O | NOx | CO | NMVOCs | SO2 |
| **1 - Energy** | 3649.200 | 3.146 | 0.244 | 29.146 | 87.920 | 11.514 | 3.588 |
| **1.A - Fuel Combustion Activities** | 3649.200 | 3.146 | 0.244 | 29.146 | 87.920 | 11.514 | 3.588 |
| **1.A.1 - Energy Industries** | 86.867 | 0.321 | 0.044 | 1.055 | 0.968 | 0.079 | 0.866 |
| 1.A.1.a - Main Activity Electricity and Heat Production | 86.867 | 0.001 | 0.001 | 0.192 | 0.008 | 0.001 | 0.751 |
| 1.A.1.a.i - Electricity Generation | 86.867 | 0.001 | 0.001 | 0.192 | 0.008 | 0.001 | 0.751 |
| 1.A.1.a.ii - Combined Heat and Power Generation (CHP) | NO | NO | NO | NO | NO | NO | NO |
| 1.A.1.a.iii - Heat Plants | NO | NO | NO | NO | NO | NO | NO |
| 1.A.1.b - Petroleum Refining | NO | NO | NO | NO | NO | NO | NO |
| 1.A.1.c - Manufacture of Solid Fuels and Other Energy Industries | NO | 0.320 | 0.043 | 0.864 | 0.960 | 0.078 | 0.115 |
| 1.A.1.c.i - Manufacture of Solid Fuels | NO | 0.320 | 0.043 | 0.864 | 0.960 | 0.078 | 0.115 |
| 1.A.1.c.ii - Other Energy Industries | NO | | | NO | NO | NO | NO |
| **1.A.2 - Manufacturing Industries and Construction** | 192.505 | 0.083 | 0.005 | 0.736 | 1.435 | 0.359 | 0.923 |
| 1.A.2.a - Iron and Steel | NO | NO | NO | NO | NO | NO | NO |
| 1.A.2.b - Non-Ferrous Metals | NO | NO | NO | NO | NO | NO | NO |
| 1.A.2.c - Chemicals | NO | NO | NO | NO | NO | NO | NO |
| 1.A.2.d - Pulp, Paper and Print | NO | NO | NO | NO | NO | NO | NO |
| 1.A.2.e - Food Processing, Beverages and Tobacco | EE | EE | EE | EE | EE | EE | EE |
| 1.A.2.f - Non-Metallic Minerals | EE | EE | EE | EE | EE | EE | EE |
| 1.A.2.g - Transport Equipment | NO | NO | NO | NO | NO | NO | NO |
| 1.A.2.h - Machinery | NO | NO | NO | NO | NO | NO | NO |
| 1.A.2.i - Mining (excluding fuels) and Quarrying | 190.067 | 0.025 | 0.004 | 0.681 | 1.197 | 0.234 | 0.917 |
| 1.A.2.j - Wood and wood products | NO | NO | NO | NO | NO | NO | NO |
| 1.A.2.k - Construction | EE | EE | EE | EE | EE | EE | EE |
| 1.A.2.l - Textile and Leather | EE | EE | EE | EE | EE | EE | EE |
| 1.A.2.m - Non-specified Industry | 2.437 | 0.058 | 0.002 | 0.055 | 0.238 | 0.125 | 0.006 |
| **1.A.3 - Transport** | 2852.747 | 0.633 | 0.158 | 18.988 | 54.242 | 5.812 | 0.027 |
| 1.A.3.a - Civil Aviation | 25.546 | 0.000 | 0.001 | 0.061 | 4.338 | 0.069 | 0.008 |
| 1.A.3.a.i - International Aviation (International Bunkers) (1) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1.A.3.a.ii - Domestic Aviation | 25.546 | 0.000 | 0.001 | 0.061 | 4.338 | 0.069 | 0.008 |
| 1.A.3.b - Road Transportation | 2778.514 | 0.630 | 0.139 | 18.111 | 49.738 | 5.669 | 0.019 |
| 1.A.3.b.i - Cars | 593.920 | 0.239 | 0.028 | 1.812 | 13.578 | 1.621 | 0.007 |
| 1.A.3.b.i.1 - Passenger cars with 3-way catalysts | 191.069 | 0.078 | 0.009 | 0.580 | 4.344 | 0.519 | 0.002 |
| 1.A.3.b.i.2 - Passenger cars without 3-way catalysts | 402.851 | 0.162 | 0.019 | 1.232 | 9.235 | 1.103 | 0.005 |
| 1.A.3.b.ii - Light-duty trucks | 1090.740 | 0.332 | 0.053 | 4.862 | 33.205 | 3.296 | 0.010 |
| 1.A.3.b.ii.1 - Light-duty trucks with 3-way catalysts | 818.055 | 0.249 | 0.040 | 3.646 | 24.904 | 2.472 | 0.007 |
| 1.A.3.b.ii.2 - Light-duty trucks without 3-way catalysts | 272.685 | 0.083 | 0.013 | 1.215 | 8.301 | 0.824 | 0.002 |

| Categories | Emissions (Gg) | | | | | | |
|---|---|---|---|---|---|---|---|
| | CO2 | CH4 | N2O | NOx | CO | NMVOCs | SO2 |
| 1.A.3.b.iii - Heavy-duty trucks and buses | 1091.631 | 0.057 | 0.057 | 11.433 | 2.597 | 0.658 | 0.003 |
| 1.A.3.b.iv - Motorcycles | 2.224 | 0.001 | 0.000 | 0.005 | 0.357 | 0.094 | 0.000 |
| 1.A.3.b.v - Evaporative emissions from vehicles | NO | NO | NO | NO | NO | NO | NO |
| 1.A.3.b.vi - Urea-based catalysts | NO | NO | NO | NO | NO | NO | NO |
| 1.A.3.c - Railways | 48.687 | 0.003 | 0.018 | 0.816 | 0.167 | 0.073 | 0.000 |
| 1.A.3.d - Water-borne Navigation | EE | EE | EE | EE | EE | EE | EE |
| 1.A.3.d.i - International water-borne navigation (International bunkers) (1) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1.A.3.d.ii - Domestic Water-borne Navigation | EE | EE | EE | EE | EE | EE | EE |
| 1.A.3.e - Other Transportation | EE | EE | EE | EE | EE | EE | EE |
| 1.A.3.e.i - Pipeline Transport | NO | NO | NO | NO | NO | NO | NO |
| 1.A.3.e.ii - Off-road | EE | EE | EE | EE | EE | EE | EE |
| **1.A.4 - Other Sectors** | 379.730 | 2.101 | 0.030 | 6.941 | 30.839 | 5.173 | 1.771 |
| 1.A.4.a - Commercial/Institutional | EE | EE | EE | EE | EE | EE | EE |
| 1.A.4.b - Residential | 110.180 | 2.064 | 0.028 | 0.586 | 27.760 | 4.162 | 0.076 |
| 1.A.4.c - Agriculture/Forestry/Fishing/Fish Farms | 269.550 | 0.037 | 0.002 | 6.354 | 3.079 | 1.011 | 1.695 |
| 1.A.4.c.i - Stationary | EE | EE | EE | EE | EE | EE | EE |
| 1.A.4.c.ii - Off-road Vehicles and Other Machinery | EE | EE | EE | EE | EE | EE | EE |
| 1.A.4.c.iii - Fishing (mobile combustion) | 269.550 | 0.037 | 0.002 | 6.354 | 3.079 | 1.011 | 1.695 |
| **1.A.5 - Non-Specified** | 137.351 | 0.008 | 0.007 | 1.426 | 0.435 | 0.091 | 0.001 |
| 1.A.5.a - Stationary | EE | EE | EE | EE | EE | EE | EE |
| 1.A.5.b - Mobile | 137.351 | 0.008 | 0.007 | 1.426 | 0.435 | 0.091 | 0.001 |
| 1.A.5.b.i - Mobile (aviation component) | EE | EE | EE | EE | EE | EE | EE |
| 1.A.5.b.ii - Mobile (water-borne component) | EE | EE | EE | EE | EE | EE | EE |
| 1.A.5.b.iii - Mobile (Other) | 137.351 | 0.008 | 0.007 | 1.426 | 0.435 | 0.091 | 0.001 |
| 1.A.5.c - Multilateral Operations (1)(2) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **1.B - Fugitive emissions from fuels** | NO | NO | NO | NO | NO | NO | NO |
| **1.B.1 - Solid Fuels** | NO | NO | NO | NO | NO | NO | NO |
| 1.B.1.a - Coal mining and handling | NO | NO | NA | NO | NO | NO | NO |
| 1.B.1.a.i - Underground mines | NO | NO | NA | NO | NO | NO | NO |
| 1.B.1.a.i.1 - Mining | NO | NO | NA | NO | NO | NO | NO |
| 1.B.1.a.i.2 - Post-mining seam gas emissions | NO | NO | NA | NO | NO | NO | NO |
| 1.B.1.a.i.3 - Abandoned underground mines | NO | NO | NA | NO | NO | NO | NO |
| 1.B.1.a.i.4 - Flaring of drained methane or conversion of methane to CO2 | NO | NO | NA | NO | NO | NO | NO |
| 1.B.1.a.ii - Surface mines | NO | NO | NA | NO | NO | NO | NO |
| 1.B.1.a.ii.1 - Mining | NO | NO | NA | NO | NO | NO | NO |
| 1.B.1.a.ii.2 - Post-mining seam gas emissions | NO | NO | NA | NO | NO | NO | NO |
| 1.B.1.b - Uncontrolled combustion and burning coal dumps | NO | NA | NA | NO | NO | NO | NO |
| 1.B.1.c - Solid fuel transformation | NO | NO | NO | NO | NO | NO | NO |
| **1.B.2 - Oil and Natural Gas** | NO | NO | NO | NO | NO | NO | NO |
| 1.B.2.a - Oil | NO | NO | NO | NO | NO | NO | NO |
| 1.B.2.a.i - Venting | NO | NO | NA | NO | NO | NO | NO |
| 1.B.2.a.ii - Flaring | NO | NO | NO | NO | NO | NO | NO |

| Categories | Emissions (Gg) | | | | | | |
|---|---|---|---|---|---|---|---|
| | CO2 | CH4 | N2O | NOx | CO | NMVOCs | SO2 |
| 1.B.2.a.iii - All Other | NO | NO | NO | NO | NO | NO | NO |
| 1.B.2.a.iii.1 - Exploration | NO | NO | NO | NO | NO | NO | NO |
| 1.B.2.a.iii.2 - Production and Upgrading | NO | NO | NO | NO | NO | NO | NO |
| 1.B.2.a.iii.3 - Transport | NO | NO | NO | NO | NO | NO | NO |
| 1.B.2.a.iii.4 - Refining | NO | NO | NA | NO | NO | NO | NO |
| 1.B.2.a.iii.5 - Distribution of oil products | NO | NO | NA | NO | NO | NO | NO |
| 1.B.2.a.iii.6 - Other | NO | NO | NO | NO | NO | NO | NO |
| 1.B.2.b - Natural Gas | NO | NO | NO | NO | NO | NO | NO |
| 1.B.2.b.i - Venting | NO | NO | NA | NO | NO | NO | NO |
| 1.B.2.b.ii - Flaring | NO | NO | NO | NO | NO | NO | NO |
| 1.B.2.b.iii - All Other | NO | NO | NO | NO | NO | NO | NO |
| 1.B.2.b.iii.1 - Exploration | NO | NO | NA | NO | NO | NO | NO |
| 1.B.2.b.iii.2 - Production | NO | NO | NA | NO | NO | NO | NO |
| 1.B.2.b.iii.3 - Processing | NO | NO | NA | NO | NO | NO | NO |
| 1.B.2.b.iii.4 - Transmission and Storage | NO | NO | NA | NO | NO | NO | NO |
| 1.B.2.b.iii.5 - Distribution | NO | NO | NA | NO | NO | NO | NO |
| 1.B.2.b.iii.6 - Other | NO | NO | NO | NO | NO | NO | NO |
| **1.B.3 - Other emissions from Energy Production** | NO | NO | NO | NO | NO | NO | NO |
| **1.C - Carbon dioxide Transport and Storage** | NO | NA | NA | NA | NA | NA | NA |
| **1.C.1 - Transport of CO2** | NO | NA | NA | NA | NA | NA | NA |
| 1.C.1.a - Pipelines | NO | NA | NA | NA | NA | NA | NA |
| 1.C.1.b - Ships | NO | NA | NA | NA | NA | NA | NA |
| 1.C.1.c - Other (please specify) | NO | NA | NA | NA | NA | NA | NA |
| **1.C.2 - Injection and Storage** | NO | NA | NA | NA | NA | NA | NA |
| 1.C.2.a - Injection | NO | NA | NA | NA | NA | NA | NA |
| 1.C.2.b - Storage | NO | NA | NA | NA | NA | NA | NA |
| **1.C.3 - Other** | NO | NA | NA | NA | NA | NA | NA |

| Categories | Emissions (Gg) | | | | | | |
|---|---|---|---|---|---|---|---|
| | CO2 | CH4 | N2O | NOx | CO | NMVOCs | SO2 |
| **Memo Items (3)** | | | | | | | |
| International Bunkers | 263.112 | 0.015 | 0.007 | 4.267 | 0.789 | 0.274 | 1.015 |
| 1.A.3.a.i - International Aviation (International Bunkers) (1) | 108.698 | 0.001 | 0.003 | 0.441 | 0.038 | 0.017 | 0.035 |
| 1.A.3.d.i - International water-borne navigation (International bunkers) (1) | 154.414 | 0.014 | 0.004 | 3.825 | 0.752 | 0.257 | 0.981 |
| 1.A.5.c - Multilateral Operations (1)(2) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **Information Items** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| CO2 from Biomass Combustion for Energy Production | 2017.287 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

# 5. Industrial Processes and Product Use (IPPU)

## 5.1. Description of IPPU sector

GHG emissions occur during the process of production of a wide range of industrial products. Emissions arise during the chemical or physical transformation of materials (for example, in the blast furnace in the iron and steel industry, ammonia and other chemical products manufactured when fossil fuels are used as chemical feedstock). The cement industry is another notable example of an industrial process that releases a significant amount of $CO_2$. During these processes, various GHGs, including $CO_2$, $CH_4$, $N_2O$, HFCs and PFCs, can be produced (IPCC 2006 Guidelines V3_1, Ch 1). Other gases also emitted in different sub-categories include $SF_6$ and NMVOCs.

Emissions were estimated for activities occurring in six out of the eight categories falling under the IPPU sector and these sub-categories are listed in Table 5.1.

**Table 5.1 - Categories and sub-categories for which emissions are reported**

| Sectoral Categories | Sub-Categories from which emissions are reported |
|---|---|
| 2.A Mineral Industry | 2.A.1 - Cement production |
| 2.D Non-Energy Products from Fuels and Solvent | 2.D.1 - Lubricant Use<br>2.D.2 – Paraffin wax use<br>2.D.3.b – Solvent Use - Paint application<br>2.D.3.c – Solvent Use - Asphalt and bitumen |
| 2.F | 2.F.1 - Refrigeration and Air Conditioning |
| 2.G | 2.G.1 - Medical Applications of $N_2O$ |
| 2.H Other | 2.H.2 - Food and Beverages Industry<br>2.H.2.a - Beer manufacturing<br>2.H.2.a - Breadmaking |

Lime production that was previously reported is no longer included as this activity has ceased in 2016. Similarly, zinc production has not been included for the whole time series as fresh information collected on the process revealed that the technology adopted for metallic zinc production in Namibia, namely solvent extraction-electrowinning (Wikipedia, accessed 18 March 2020), is a non-emitter of GHGs. A few more activity areas still must be included given that AD were still not available to compute the estimates, despite special efforts being devoted to collect these AD when this inventory was prepared. A survey is under way for estimating $SF_6$ from electrical equipment. These sources are.

- **Product used as substitutes for ozone depleting substances**
  - Fire protection
  - Aerosols
  - Solvents
- **Other products manufacture and use**
  - Disposal of electric equipment
  - $SF_6$ in military applications
  - $N_2O$ used as propellant for pressure and aerosol products.

- **Food and beverage industry**
    - Fishmeal production

## 5.2. Methods

The method adopted is according to the 2006 IPCC Guidelines, at the Tier 1 level, due to unavailability of disaggregated information on the technologies used in the production processes for moving to higher Tiers. As well, these emitting sources are not key categories in most cases. Emissions of $CO_2$, $N_2O$ and HFCs were estimated through computations made using the 2006 IPCC software. NMVOCs were estimated using Excel for programming the equations recommended in the EMEP/EEA guidebook.

## 5.3. Activity Data

AD for the IPPU sector were obtained mainly from the NSA and complemented with those collected from the industrialists. All AD from the different sources were compared and quality controlled to identify the most reliable sets which were then used in the software for generating emissions. AD for lubricants and paraffin wax use were derived from the mass balance of import and export data. AD used for the time series are provided in Table 5.6.

### 5.3.1. Cement Production (2.A.1)

During the period under review there was only one cement production plant in operation in Namibia, namely, the Ohorongo Cement Plant (Ohorongo (Pty) Ltd), which according to the company's website[1] has a production capacity of over 1 million tonnes of cement per year. AD for this sub-category is based on clinker utilisation which is equivalent to production as there is no import in the country by the manufacturer.

Cement production started in 2011 and from that year to 2014, cement production increased steadily, as indicated by clinker utilisation which increased from 284,000 tonnes/year at the beginning of the period to reach 635,000 tonnes by 2015 which regressed to 505,047 tonnes in 2016 (Table 5.2).

It is worth noting that the cement plant claims to be one of the lowest $CO_2$ emitting cement factory in the world on account of its use of alternative fuels, namely wood chips derived from encroacher bushes and charcoal fines as well as an energy-efficient production process.

### 5.3.2. Lubricant Use (2.D.1)

Activity data gaps for Lubricant Use were generated from data collected for the period 2000 to 2013 from Trade Statistics and the Ministry of Industrialisation, Trade and SME. The average lubricant use for 2000 and 2001 was used as a constant for the period 1990 to 1999. Since trade data were not reliable for the period 2014 to 2016, the average usage during the period 2011 to 2013 was adopted. The time series thus obtained shows: (i) lubricant use was stable during the 1991 to 1999 period with an annual use of 854 tonnes, (ii) from 2004 to 2009 lubricant use jumped from 294 tonnes to 15,404

[1] www.ohrongo-cement.com

tonnes and (iii) thereafter, with the exception of a drop to 13,896 tonnes in 2010, usage stabilised at around 15,400 tonnes per year (Table 5.6).

### 5.3.3. Paraffin Wax Use (2.D.2)

For the period 2000 to 2010, AD for Paraffin Wax Use were generated by adjusting those obtained from the Ministry of Industrialisation, Trade and SME with data from Trade Statistics. For the periods 1990 to 1999 and that of 2011 to 2016, an estimate of 30,000 tonnes per year was used (Table 5.2).

### 5.3.4. Wood Preservation (2.D.3.a)

The utilisation of creosote by the railway network was considered and the assumption made that over the period under review utilisation was constant given that the railway network did not expand. Thus, AD for creosote was estimated at 16 tonnes per year based on average trade data (Table 5.6).

### 5.3.5. Paint application (2.D.3.b)

Since no production data were available from manufacturers of solvent-based paints and lacquers, the mass balance from import and export data was adopted as AD for this activity. Extrapolation of data available for the period 1998 to 2016 was adopted to generate data for the period 1990 to 1997. A linear trend was then generated for the whole period to correct the marked highs and lows of the original trade data (Table 5.6).

### 5.3.6. Asphalt and bitumen (2.D.3.c)

Asphalt and bitumen import and export data available for the period 1998 to 2016 presented marked variations between the years. AD for the period 1991 to 1997 was computed as the average amount of product used during the period 1998 to 2003, import-export data were retained for the period 1998 to 2002 and linear trending of import and export data of the period 2003 to 2016 was used to generate data for completing the time series. Asphalt and bitumen used during the period 1998 to 2003 was mainly for maintenance purposes while the steady increase from 2004 onwards was due to development of the road network (Table 5.6).

**Table 5.2 - Activity data for the above IPPU categories 2.A and 2.D (1990 - 2016)**

| Year | 2.A.1-Cement production (t) | 2.A.2-Lime production (t) | 2.D.1-Lubricant use (t) | 2.D.2-Paraffin Wax Use (t) | 2.D.3.a-Wood preservation (creosote) (t) | 2.D.3.b-Paint application (Non-aqueous paint) (t) | 2.D.3.c-Asphalt and bitumen (t) |
|---|---|---|---|---|---|---|---|
| 1990 | * | 2,153 | 854 | 30,000 | 16 | 1,899 | 485 |
| 1991 | * | 2,903 | 854 | 30,000 | 16 | 2,089 | 485 |
| 1992 | * | 3,652 | 854 | 30,000 | 16 | 2,278 | 485 |
| 1993 | * | 4,402 | 854 | 30,000 | 16 | 2,467 | 485 |
| 1994 | * | 5,152 | 854 | 30,000 | 16 | 2,657 | 485 |
| 1995 | * | 5,901 | 854 | 30,000 | 16 | 2,846 | 485 |
| 1996 | * | 6,651 | 854 | 30,000 | 16 | 3,036 | 485 |
| 1997 | * | 7,401 | 854 | 30,000 | 16 | 3,225 | 485 |
| 1998 | * | 8,151 | 854 | 30,000 | 16 | 3,415 | 742 |
| 1999 | * | 8,900 | 854 | 30,000 | 16 | 3,604 | 92 |
| 2000 | * | 9,161 | 965 | 29,415 | 16 | 3,793 | 263 |

| Year | 2.A.1-Cement production (t) | 2.A.2-Lime production (t) | 2.D.1-Lubricant use (t) | 2.D.2-Paraffin Wax Use (t) | 2.D.3.a-Wood preservation (creosote) (t) | 2.D.3.b-Paint application (Non-aqueous paint) (t) | 2.D.3.c-Asphalt and bitumen (t) |
|---|---|---|---|---|---|---|---|
| 2001 | * | 10,735 | 448 | 27,319 | 16 | 3,983 | 1,175 |
| 2002 | * | 11,200 | 294 | 29,577 | 16 | 4,172 | 1,047 |
| 2003 | * | 12,400 | 2,022 | 30,332 | 16 | 4,362 | 2,672 |
| 2004 | * | 12,600 | 543 | 34,193 | 16 | 4,551 | 4,297 |
| 2005 | * | 13,050 | 6,179 | 30,765 | 16 | 4,740 | 5,921 |
| 2006 | * | 13,500 | 6,966 | 29,070 | 16 | 4,930 | 7,546 |
| 2007 | * | 14,500 | 11,197 | 29,128 | 16 | 5,119 | 9,171 |
| 2008 | * | 15,400 | 14,880 | 34,625 | 16 | 5,309 | 10,796 |
| 2009 | * | 17,600 | 15,404 | 35,989 | 16 | 5,498 | 12,421 |
| 2010 | * | 19,800 | 13,896 | 27,529 | 16 | 5,687 | 14,045 |
| 2011 | 284,000 | 18,996 | 15,205 | 24,000 | 16 | 5,877 | 15,670 |
| 2012 | 428,000 | 19,890 | 15,231 | 21,180 | 16 | 6,066 | 17,295 |
| 2013 | 520,000 | 20,785 | 15,681 | 18,361 | 16 | 6,256 | 18,920 |
| 2014 | 583,000 | 21,679 | 15,372 | 15,541 | 16 | 6,445 | 20,545 |
| 2015 | 635,000 | 22,573 | 15,372 | 12,721 | 16 | 6,635 | 22,169 |
| 2016 | 505,047 | * | 15,372 | 9,901 | 16 | 6,824 | 23,794 |

### 5.3.7. Refrigeration and Air Conditioning (2.F.1)

***Description of the Refrigeration and Air Conditioning (RAC) sub-category***

Emissions from fluorinated gases used as substitutes for ODS occur from product use, namely PFCs and HFCs. These gases are used in the production of foam blowing agents, aerosols, fire suppression and other applications. These gases have been introduced on the market in RAC to replace Ozone Depleting Substances following the entry into force of the Montreal Protocol during the mid-1990's.

Emissions of PFCs and HFCs occur during the production of these gases, their use and when equipment containing them are disposed of. These specialized production units are mostly found in the northern hemisphere. Their use in RAC equipment is the major source of emissions occurring in Namibia. These gases are present in equipment requiring air temperature control such as refrigerators, chillers, air conditioners cars and other vehicles among others. Leakages from the gas system occur during the lifetime of the equipment. Gases can also escape during recharge of the cooling system and at the end of the lifetime of the equipment when the latter is disposed of.

Thus, the continuous influx of new equipment on the market contribute to what is called a bank and small amounts are lost through leakages continuously from that bank. Major emissions occur when the equipment is retired without recovery of the residual charge

***Method***

The Tier 1 method with mass balance approach B as per Table 7.2 recommended in the IPCC 2006 Guidelines V3_7_Ch7_ODS_Subtitutes was adopted for estimating emissions from this sub-category.

## *Activity data*

It has not been possible for Namibia to report on this subcategory before as data was scanty. Available trade statistics are not disaggregated enough to allow tracking of the different gas types and number of equipment imported.

A recent study was done by GIZ (German Agency for International Cooperation) in 2016 whereby resources were available to further inquire at customs levels and undertake surveys with importers and users of these gases in the industry. Information from that study was partially used to produce a time series for this sub-category. Available information from the report covered:

- Refrigeration and stationary air conditioning
  - New equipment sales from 2010 to 2016 for each type
  - Existing equipment in each year from 2010 to 2016 by equipment type
  - Charge of refrigerant gas in new equipment
  - Refrigerant gas used in each equipment type
  - Mobile air conditioning
  - Refrigerant gas used in vehicles in Namibia

The information from 2010 to 2016 was used to generate data for missing years in the timeseries based on the population growth rate of urban regions of Namibia which is estimated to be at 3.88% annually during the period 1990 to 2000 and 4.11 % for the period 2001 to 2010.

Data obtained from the institution responsible for road transport in Namibia and used for estimating emissions for this category in the Energy sector were used to calculate the annual number of new vehicles entering the market. The AD generated on charge per vehicle by the number is presented in Table 5.3. R410a gas used in stationary air conditioning consists of R32 and R125 on a 1:1 basis while R507 used in commercial refrigeration is a 1:1 mix of R125 and R143 as well as R134a.

**Table 5.3 - Amount of refrigerant (kg) in new equipment on an annual basis**

| | **Stationary air conditioning** | | **Mobile air conditioning** | **Commercial refrigeration** | | |
|---|---|---|---|---|---|---|
| **Year** | R32 | R125 | R 134A | R125 | R134a | R143 |
| 1993 | - | - | - | - | 774 | - |
| 1994 | - | - | - | - | 804 | - |
| 1995 | 6,153 | 6,153 | 6,907 | 4,324 | 835 | 4,324 |
| 1996 | 6,391 | 6,391 | 7,175 | 4,492 | 867 | 4,492 |
| 1997 | 6,639 | 6,639 | 7,453 | 4,666 | 901 | 4,666 |
| 1998 | 6,897 | 6,897 | 7,742 | 4,847 | 936 | 4,847 |
| 1999 | 7,165 | 7,165 | 8,042 | 5,035 | 972 | 5,035 |
| 2000 | 7,443 | 7,443 | 8,354 | 5,230 | 1,010 | 5,230 |
| 2001 | 7,749 | 7,749 | 8,698 | 5,445 | 1,051 | 5,445 |
| 2002 | 8,067 | 8,067 | 7,938 | 5,669 | 1,095 | 5,669 |
| 2003 | 8,399 | 8,398 | 10,382 | 5,902 | 1,140 | 5,902 |
| 2004 | 8,744 | 8,744 | 10,350 | 6,145 | 1,186 | 6,145 |
| 2005 | 9,103 | 9,103 | 11,081 | 6,397 | 1,235 | 6,397 |
| 2006 | 9,477 | 9,477 | 11,766 | 6,660 | 1,286 | 6,660 |

| | Stationary air conditioning | | Mobile air conditioning | Commercial refrigeration | | |
|---|---|---|---|---|---|---|
| **Year** | R32 | R125 | R 134A | R125 | R134a | R143 |
| 2007 | 9,867 | 9,867 | 12,179 | 6,934 | 1,339 | 6,934 |
| 2008 | 10,272 | 10,272 | 9,214 | 7,219 | 1,394 | 7,219 |
| 2009 | 10,694 | 10,694 | 11,553 | 7,516 | 1,451 | 7,516 |
| 2010 | 6,489 | 6,489 | 12,895 | 7,043 | 895 | 7,043 |
| 2011 | 17,440 | 17,440 | 13,942 | 8,957 | 2,242 | 8,957 |
| 2012 | 9,471 | 9,471 | 13,949 | 7,473 | 1,396 | 7,473 |
| 2013 | 17,086 | 17,086 | 14,069 | 8,081 | 1,955 | 8,081 |
| 2014 | 22,448 | 22,448 | 17,705 | 9,831 | 2,729 | 9,831 |
| 2015 | 21,010 | 21,010 | 18,029 | 9,318 | 2,385 | 9,318 |
| 2016 | 20,984 | 20,984 | 15,150 | 9,700 | 2,568 | 9,700 |

It is assumed that all the gases came on the market in new equipment as from 1995 except R134a in commercial refrigeration. Unfortunately, it has not been possible to include import and export data in the calculations as disaggregated data by gas was unavailable. This constitutes an underestimate of the emissions as gas, used to recharge an equipment which leaks, will eventually escape over subsequent years.

### *Emission factors*

The different gases used as ODS substitutes have different GWP. EFs and details on the gases are given in Table 5.4. The parameters for the constitution of the bank and subsequent emissions from the bank is also given in the same Table. Furthermore, R 600 A (Iso-butane) is not regulated under the Convention and thus not needed to report on.

**Table 5.4 - Emission factors used for estimating emissions from RAC (2.F)**

| | Stationary air conditioning | | Mobile air conditioning | Commercial refrigeration | | |
|---|---|---|---|---|---|---|
| | R32 | R125 | R 134A | R134a | R125 | R143 |
| Year of introduction | 1995 | | 1995 | 1993 | 1995 | |
| Growth rate (%) | 7 | | 6 | 9 | 10 | |
| Lifetime (years) | 9 | | 20 | 10 | 10 | |
| Emission factor (%) | 5 | | 15 | 15 | 15 | |

## 5.3.8. $N_2O$ from Product Use (2.G.3) - (Medical Applications 2.G.3.a)

### *Description of the Medical application sub-category*

$N_2O$ is used as an anaesthesia gas during surgical operations. It can also be used for pain relief and in veterinary applications. The gas is assumed to be breathed in by patients and released back to the atmosphere chemically unchanged.

### *Method*

A Tier 1 method was used to estimate the emissions from this sub-category.

## *Activity data*

National statistics is not disaggregated enough to obtain the amount of gas imported/exported and hence used. A timeseries was constructed based on the following assumptions.

- Number of operations per 100,000 inhabitants for years 1990 and 2010 (WHO website)
- 90 grams of $N_2O$ used per operation. (personal communication)

Table 5.2 gives the AD used.

**Table 5.2 - Amount of $N_2O$ used in medical applications on an annual basis (1990 - 2016)**

| Year | Population | Number of surgical operations per 100,000 persons | Total number of operations | Amount of $N_2O$ (t) used |
|---|---|---|---|---|
| 1990 | 1,436,212 | 2,000 | 28,724 | 2.59 |
| 1991 | 1,489,782 | 2,080 | 30,987 | 2.79 |
| 1992 | 1,520,770 | 2,160 | 32,849 | 2.96 |
| 1993 | 1,552,402 | 2,240 | 34,774 | 3.13 |
| 1994 | 1,584,692 | 2,320 | 36,765 | 3.31 |
| 1995 | 1,617,653 | 2,400 | 38,824 | 3.49 |
| 1996 | 1,651,300 | 2,480 | 40,952 | 3.69 |
| 1997 | 1,685,647 | 2,560 | 43,153 | 3.88 |
| 1998 | 1,720,709 | 2,640 | 45,427 | 4.09 |
| 1999 | 1,756,500 | 2,720 | 47,777 | 4.30 |
| 2000 | 1,793,035 | 2,800 | 50,205 | 4.52 |
| 2001 | 1,830,330 | 2,880 | 52,714 | 4.74 |
| 2002 | 1,856,138 | 2,960 | 54,942 | 4.94 |
| 2003 | 1,882,309 | 3,040 | 57,222 | 5.15 |
| 2004 | 1,908,850 | 3,120 | 59,556 | 5.36 |
| 2005 | 1,935,765 | 3,200 | 61,944 | 5.58 |
| 2006 | 1,963,059 | 3,280 | 64,388 | 5.79 |
| 2007 | 1,990,738 | 3,360 | 66,889 | 6.02 |
| 2008 | 2,018,807 | 3,440 | 69,447 | 6.25 |
| 2009 | 2,047,273 | 3,520 | 72,064 | 6.49 |
| 2010 | 2,076,139 | 3,600 | 74,741 | 6.73 |
| 2011 | 2,105,413 | 3,680 | 77,479 | 6.97 |
| 2012 | 2,136,036 | 3,760 | 80,315 | 7.23 |
| 2013 | 2,167,105 | 3,840 | 83,217 | 7.49 |
| 2014 | 2,198,625 | 3,920 | 86,186 | 7.76 |
| 2015 | 2,230,604 | 4,000 | 89,224 | 8.03 |
| 2016 | 2,263,048 | 4,080 | 92,332 | 8.31 |

## *Emission factors (2.G)*

Since all the gas used is expected to be sent to the atmosphere, an EF of 1 applies to this sub-category.

### 5.3.9. Beer manufacturing (2.H.2.a)

Past efforts to obtain data from the beer manufacturer has been unsuccessful. Thus, production of beer was calculated by summing the amount of beer consumed locally with the amount exported. In turn, the amount of beer consumed was derived from data on the amount of alcohol consumed in the form of beer based on FAO data which were adjusted for Namibia.

The AD so obtained show that beer production has steadily increased at an average rate of about 18,000 tonnes per year over the 27-year period under review, to reach almost 513,000 tonnes in 2016.

### 5.3.10. Bread Making (2.H.2.a)

Data from various sources were studied prior to the generation of AD for Bread Making activity. Since trade statistics were found unreliable, AD were computed as the average of FAO and the Agricultural Statistical Bulletin on wheat consumption. The AD so obtained showed that wheat consumption increased from 32,860 tonnes in 1990 to reach 95,993 tonnes in 2016.

An extraction rate of 80% of this wheat was adopted to generate flour produced and the latter converted to bread at the rate of 610 g of flour per kg of bread.

**Table 5.6 - Activity data for the Beer Manufacturing and Breadmaking (1990 - 2016)**

| Year | 2.H.2.a-Beer manufacturing (t) | 2.D.H.2.a-Bread making (wheat) (t) |
|---|---|---|
| 1990 | 8,258 | 35,333 |
| 1991 | 8,566 | 32,860 |
| 1992 | 6,843 | 41,886 |
| 1993 | 6,986 | 43,913 |
| 1994 | 9,904 | 45,939 |
| 1995 | 9,908 | 55,865 |
| 1996 | 9,908 | 60,950 |
| 1997 | 42,141 | 45,646 |
| 1998 | 113,177 | 60,953 |
| 1999 | 156,568 | 75,648 |
| 2000 | 202,498 | 64,218 |
| 2001 | 258,058 | 65,271 |
| 2002 | 185,268 | 83,019 |
| 2003 | 264,395 | 80,685 |
| 2004 | 248,612 | 88,614 |
| 2005 | 264,516 | 85,699 |
| 2006 | 282,645 | 73,770 |
| 2007 | 291,301 | 74,914 |
| 2008 | 328,516 | 67,798 |
| 2009 | 393,881 | 70,136 |
| 2010 | 367,496 | 74,892 |
| 2011 | 385,193 | 79,918 |
| 2012 | 410,695 | 85,445 |
| 2013 | 427,188 | 89,471 |

| Year | 2.H.2.a-Beer manufacturing (t) | 2.D.H.2.a-Bread making (wheat) (t) |
|---|---|---|
| 2014 | 397,039 | 91,879 |
| 2015 | 428,890 | 93,936 |
| 2016 | 512,880 | 95,993 |

## 5.4. Emission factors

In the absence of information on technology used, all EFs used were IPCC defaults, with those giving the highest emissions adopted as per Good Practice and backed by those from the EMEP/EEA 2016 Guidebook when not available from the IPCC Guidelines. When the choice was linked to the country's development level, the factor associated with developing countries was chosen. The EFs used for the different source categories are listed in Table 5.3.

**Table 5.3 – Sources for EFs for the IPPU sector**

| Category | IPPC 2006 Guidelines and EMEP/EEA Guidebook | Table and page No. |
|---|---|---|
| Cement | V3_2_Ch2 Mineral Industry | Chapter 2.2.1.2 Page 2.11 |
| Lime | V3_2_Ch2 Mineral Industry | Table 2.4 Page 2.22 |
| Zinc | V3_4_$CH_4$ Metal Industry | Table 4.24 Page 4.80 |
| Lubricant | V3_5_Ch5 Non-Energy Products | Table 5.2 Page 5.9 |
| Paraffin wax | V3_5_Ch5 Non-Energy Products | Chapter 5.3.2.2 Page 5.12 |
| Refrigeration and Air Conditioning | V3_7_Ch7 ODS substitutes | Table 7.9 Page 7.52 |
| Medical Applications ($N_2O$) | V3_8_Ch8 Other Products | Page 8.36 Section 8.4.2.2 |
| Wood preservation | EMEP/EEA - SNAP 060406 | Table 3.5 - Page 15 |
| Paint application | EMEP/EEA - SNAP 0601063 and 060104 | Table 3.3 Page 17 |
| Asphalt and bitumen | EMEP/EEA - SNAP 040611 | Table 3.1 Page 8 |
| Beer manufacturing | EMEP/EEA - SNAP 060407 | Table 3-1 Page 7 |
| Bread making | EMEP/EEA - SNAP 060405 | Table 3-1 Page 7 |

## 5.5. Emission estimates

### Aggregated emissions by gas for inventory year 2016

#### 5.5.1.1. Direct gases and HFCs

Three direct gases $CO_2$, $N_2O$ and HFCs, were emitted from the IPPU Sector in 2016. The emissions amounted to 400.93 Gg $CO_2$-eq (Table 5.5). The highest emitter in 2016 was the Cement industry with 262.62 Gg $CO_2$-eq. The remaining sub-categories are less important emitters as depicted in Figure 5.1.

The second gas in importance, the HFCs, from Refrigeration and air Conditioning was at 119.55 Gg $CO_2$-eq while $N_2O$ emitted from medical uses stood at 2.53 Gg $CO_2$-eq in 2016.

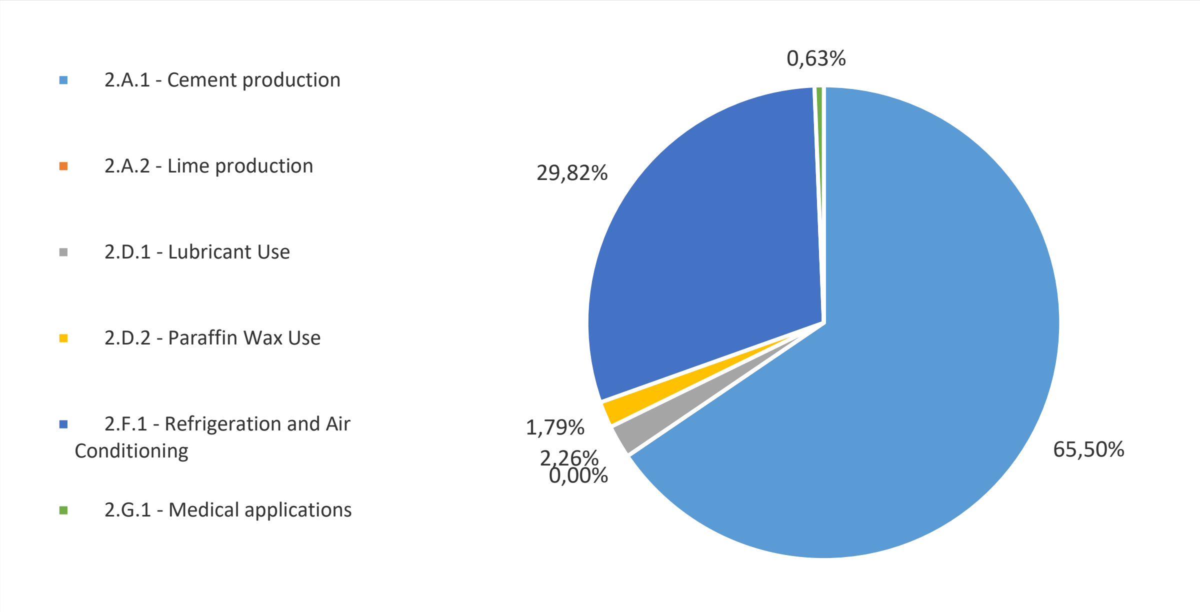


**Figure 5.1- Percentage distribution of emissions for IPPU Sector (2016)**

### 5.5.1.2. Indirect gases

The only indirect gas that were emitted by the IPPU sector in 2016 were NMVOCs and emissions reached 2.64 Gg (Table 5.4).

**Table 5.4 - Emissions of NMVOCs from the IPPU Sector for inventory year 2016**

| Categories | NMVOCs (Gg) |
|---|---|
| 2 - Industrial Processes and Product Use | 2.64 |
| 2.A.1 - Cement production | NA |
| 2.A.2 - Lime production | NA |
| 2.C.6 - Zinc Production | NA |
| 2.D.1 - Lubricant Use | NA |
| 2.D.2 - Paraffin Wax Use | NA |
| 2.D.3 - Solvent Use | 1.37 |
| 2.H.2 - Food and Beverages Industry | 1.28 |

## 5.5.2. Emissions trend of direct GHGs by category for the period 1990 to 2016

### 5.5.2.1. Direct gases

$CO_2$ emissions from IPPU Sector during the period 1990 to 2016 are given in Table 5.5. The total emissions of 400.93 Gg $CO_2$-eq originated mainly from Cement Production and Refrigeration and Air Conditioning activities which represented 65.5% and 29.8% respectively. The remaining 4.7% emissions originated from Lubricant use, Paraffin Wax Use and Medical Applications of $N_2O$.

**Table 5.5 - Emission trends of Direct gases (Gg $CO_2$ -eq) by category of IPPU Sector (period 1990 - 2016)**

| Year | 2.A.1 - Cement production | 2.A.2 - Lime production | 2.D.1 - Lubricant Use | 2.D.2 - Paraffin Wax Use | 2.F.1 – Refrigeration and Air Conditioning | 2.G.1 – Medical Applications of $N_2O$ | Total IPPU Sector |
|---|---|---|---|---|---|---|---|
| 1990 | NO | 2.24 | 0.50 | 17.69 | - | 0.80 | 21.20 |
| 1991 | NO | 2.24 | 0.50 | 17.69 | - | 0.86 | 21.29 |
| 1992 | NO | 2.81 | 0.50 | 17.69 | - | 0.89 | 21.89 |
| 1993 | NO | 3.39 | 0.50 | 17.69 | 0.15 | 0.94 | 22.67 |
| 1994 | NO | 3.97 | 0.50 | 17.69 | 0.28 | 1.00 | 23.44 |
| 1995 | NO | 4.54 | 0.50 | 17.69 | 5.88 | 1.05 | 29.67 |
| 1996 | NO | 5.12 | 0.50 | 17.69 | 11.03 | 1.11 | 35.45 |
| 1997 | NO | 5.70 | 0.50 | 17.69 | 15.79 | 1.17 | 40.85 |
| 1998 | NO | 6.28 | 0.50 | 17.69 | 20.24 | 1.24 | 45.95 |
| 1999 | NO | 6.85 | 0.50 | 17.69 | 24.43 | 1.30 | 50.78 |
| 2000 | NO | 7.05 | 0.57 | 17.34 | 28.41 | 1.37 | 54.74 |
| 2001 | NO | 8.27 | 0.26 | 16.11 | 32.23 | 1.44 | 58.30 |
| 2002 | NO | 8.62 | 0.73 | 17.44 | 35.71 | 1.50 | 64.01 |
| 2003 | NO | 9.55 | 1.19 | 17.88 | 40.26 | 1.56 | 70.45 |
| 2004 | NO | 9.70 | 2.42 | 20.16 | 47.44 | 1.63 | 81.35 |
| 2005 | NO | 10.05 | 3.64 | 18.14 | 89.35 | 1.69 | 122.88 |
| 2006 | NO | 10.40 | 4.11 | 17.14 | 91.00 | 1.76 | 124.40 |
| 2007 | NO | 11.17 | 6.60 | 17.17 | 92.64 | 1.83 | 129.41 |
| 2008 | NO | 11.86 | 8.77 | 20.41 | 85.84 | 1.90 | 128.79 |
| 2009 | NO | 13.55 | 9.08 | 21.22 | 85.68 | 1.97 | 131.51 |
| 2010 | NO | 15.25 | 8.19 | 16.23 | 84.60 | 2.05 | 126.32 |
| 2011 | 147.68 | 14.63 | 8.96 | 17.69 | 89.69 | 2.12 | 280.77 |
| 2012 | 222.56 | 15.32 | 8.98 | 15.58 | 91.15 | 2.20 | 355.78 |
| 2013 | 270.40 | 16.00 | 9.25 | 13.48 | 94.65 | 2.28 | 406.06 |
| 2014 | 303.16 | 16.69 | 9.06 | 11.37 | 100.68 | 2.36 | 443.32 |
| 2015 | 330.20 | 17.38 | 9.06 | 9.25 | 113.16 | 2.45 | 481.51 |
| 2016 | 262.62 | NO | 9.06 | 7.16 | 119.55 | 2.53 | 400.93 |

## 5.5.3. Emission trends of Indirect GHGs by sub-category for inventory period 1990 to 2016

### 5.5.3.1. Indirect gases

NMVOCs emissions came from the sub-categories Solvent Use and Food and Beverages covering five activities, namely Wood Preservation, Paint Application, Asphalt and Bitumen use, Beer Manufacturing and Bread Making (Table 5.6).

In 2016, a total amount of 2.64 Gg of NMVOCs were emitted by the IPPU sector, the two sub-categories contributing about 50% each. Total emissions of NMVOCs increased from 0.49 Gg in 1990 to 2.64 Gg in 2016.

**Table 5.6 - NMVOCs emission trends for IPPU sector source categories (1990 - 2016)**

| Year | 2.D.3 - Solvent | 2.H.2 - Food and Beverages Industry | Total IPPU Sector |
|---|---|---|---|
| 1991 | 0.38 | 0.11 | 0.49 |
| 1991 | 0.42 | 0.10 | 0.52 |

| Year | 2.D.3 - Solvent | 2.H.2 - Food and Beverages Industry | Total IPPU Sector |
|---|---|---|---|
| 1992 | 0.46 | 0.12 | 0.58 |
| 1993 | 0.50 | 0.13 | 0.62 |
| 1994 | 0.53 | 0.14 | 0.67 |
| 1995 | 0.57 | 0.17 | 0.74 |
| 1996 | 0.61 | 0.18 | 0.79 |
| 1997 | 0.65 | 0.20 | 0.85 |
| 1998 | 0.68 | 0.39 | 1.07 |
| 1999 | 0.72 | 0.51 | 1.23 |
| 2000 | 0.76 | 0.57 | 1.33 |
| 2001 | 0.80 | 0.69 | 1.49 |
| 2002 | 0.84 | 0.59 | 1.42 |
| 2003 | 0.87 | 0.74 | 1.61 |
| 2004 | 0.91 | 0.73 | 1.64 |
| 2005 | 0.95 | 0.75 | 1.70 |
| 2006 | 0.99 | 0.76 | 1.75 |
| 2007 | 1.03 | 0.78 | 1.80 |
| 2008 | 1.06 | 0.83 | 1.90 |
| 2009 | 1.10 | 0.97 | 2.07 |
| 2010 | 1.14 | 0.93 | 2.07 |
| 2011 | 1.18 | 0.98 | 2.16 |
| 2012 | 1.22 | 1.05 | 2.26 |
| 2013 | 1.25 | 1.09 | 2.34 |
| 2014 | 1.29 | 1.04 | 2.33 |
| 2015 | 1.33 | 1.10 | 2.43 |
| 2016 | 1.37 | 1.28 | 2.64 |

## Table 5.7 - Sectoral Table IPPU sector (Inventory Year: 2016)

| Categories | (Gg) | | | CO2 Equivalents(Gg) | | | | (Gg) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CO2 | CH4 | N2O | HFCs | PFCs | SF6 | Other halogenated gases with CO2 equivalent conversion factors (1) | Other halogenated gases without CO2 equivalent conversion factors (2) | NOx | CO | NMVOCs | SO2 |
| **2 - Industrial Processes and Product Use** | 278.846 | 0.000 | 0.008 | 119.551 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 2.644 | 0.000 |
| **2.A - Mineral Industry** | 262.624 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2.A.1 - Cement production | 262.624 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 2.A.2 - Lime production | NO | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 2.A.3 - Glass Production | NO | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 2.A.4 - Other Process Uses of Carbonates | 0.000 | 0.000 | 0.000 | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.A.4.a - Ceramics | NO | NO | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 2.A.4.b - Other Uses of Soda Ash | NO | NO | NO | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.A.4.c - Non Metallurgical Magnesia Production | NO | NO | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 2.A.4.d - Other (please specify) (3) | NO | NO | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.A.5 - Other (please specify) (3) | NO | NO | NO | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| **2.B - Chemical Industry** | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 2.B.1 - Ammonia Production | NO | NA | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.B.2 - Nitric Acid Production | NA | NA | NO | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.B.3 - Adipic Acid Production | NA | NA | NO | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.B.4 - Caprolactam, Glyoxal and Glyoxylic Acid Production | NA | NA | NO | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.B.5 - Carbide Production | NO | NO | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.B.6 - Titanium Dioxide Production | NO | NA | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.B.7 - Soda Ash Production | NO | NA | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |

| Categories | (Gg) | | | CO2 Equivalents(Gg) | | | | (Gg) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CO2 | CH4 | N2O | HFCs | PFCs | SF6 | Other halogenated gases with CO2 equivalent conversion factors (1) | Other halogenated gases without CO2 equivalent conversion factors (2) | NOx | CO | NMVOCs | SO2 |
| 2.B.8 - Petrochemical and Carbon Black Production | NO | NO | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.B.8.a - Methanol | NO | NO | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.B.8.b - Ethylene | NO | NO | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.B.8.c - Ethylene Dichloride and Vinyl Chloride Monomer | NO | NO | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.B.8.d - Ethylene Oxide | NO | NO | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.B.8.e - Acrylonitrile | NO | NO | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.B.8.f - Carbon Black | NO | NO | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.B.9 - Fluorochemical Production | NA | NA | NA | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 2.B.9.a - By-product emissions (4) | NA | NA | NA | NO | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.B.9.b - Fugitive Emissions (4) | NA | NA | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.B.10 - Other (Please specify) (3) | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| **2.C - Metal Industry** | 0.000 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 2.C.1 - Iron and Steel Production | NO | NO | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.C.2 - Ferroalloys Production | NO | NO | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.C.3 - Aluminium production | NO | NA | NA | NA | NO | NA | NA | NA | NO | NO | NO | NO |
| 2.C.4 - Magnesium production (5) | NO | NA | NA | NA | NA | NO | NA | NA | NO | NO | NO | NO |
| 2.C.5 - Lead Production | NO | NA | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.C.6 - Zinc Production | NA | NA | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.C.7 - Other (please specify) (3) | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| **2.D - Non-Energy Products from Fuels and Solvent Use (6)** | 16.221 | NO | NO | NA | NA | NA | NA | NA | NO | NO | 1.367 | NO |

| Categories | (Gg) | | | CO2 Equivalents(Gg) | | | | (Gg) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CO2 | CH4 | N2O | HFCs | PFCs | SF6 | Other halogenated gases with CO2 equivalent conversion factors (1) | Other halogenated gases without CO2 equivalent conversion factors (2) | NOx | CO | NMVOCs | SO2 |
| 2.D.1 - Lubricant Use | 9.064 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 2.D.2 - Paraffin Wax Use | 7.157 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 2.D.3 - Solvent Use (7) | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 1.367 | NA |
| 2.D.4 - Other (please specify) (3), (8) | NO | NO | NO | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| **2.E - Electronics Industry** | NO | NO | NO | NO | NO | NO | NO | NO | NA | NA | NA | NA |
| 2.E.1 - Integrated Circuit or Semiconductor (9) | NA | NA | NA | NO | NO | NO | NO | NO | NA | NA | NA | NA |
| 2.E.2 - TFT Flat Panel Display (9) | NA | NA | NA | NA | NO | NO | NO | NO | NA | NA | NA | NA |
| 2.E.3 - Photovoltaics (9) | NA | NA | NA | NA | NO | NA | NO | NO | NA | NA | NA | NA |
| 2.E.4 - Heat Transfer Fluid (10) | NA | NA | NA | NA | NO | NA | NO | NO | NA | NA | NA | NA |
| 2.E.5 - Other (please specify) (3) | NO | NO | NO | NO | NO | NO | NO | NO | NA | NA | NA | NA |
| **2.F - Product Uses as Substitutes for Ozone Depleting Substances** | NA | NA | NA | 119.551 | NE | NA | NA | NA | NA | NA | NA | NA |
| 2.F.1 - Refrigeration and Air Conditioning | NA | NA | NA | 119.551 | NA | NA | NA | NA | NA | NA | NA | NA |
| 2.F.1.a - Refrigeration and Stationary Air Conditioning | NA | NA | NA | 96.204 | NA | NA | NA | NA | NA | NA | NA | NA |
| 2.F.1.b - Mobile Air Conditioning | NA | NA | NA | 23.346 | NA | NA | NA | NA | NA | NA | NA | NA |
| 2.F.2 - Foam Blowing Agents | NA | NA | NA | NO | NA | NA | NA | NA | NA | NA | NA | NA |
| 2.F.3 - Fire Protection | NA | NA | NA | NE | NE | NA | NA | NA | NA | NA | NA | NA |
| 2.F.4 - Aerosols | NA | NA | NA | NE | NA | NA | NA | NA | NA | NA | NA | NA |
| 2.F.5 - Solvents | NA | NA | NA | NE | NE | NA | NA | NA | NA | NA | NA | NA |
| 2.F.6 - Other Applications (please specify) (3) | NA | NA | NA | NO | NO | NA | NA | NA | NA | NA | NA | NA |
| **2.G - Other Product Manufacture and Use** | NO | NO | NE | NO | NE | NE | NO | NE | NA | NA | NA | NA |

| Categories | (Gg) | | | CO2 Equivalents(Gg) | | | | | (Gg) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CO2 | CH4 | N2O | HFCs | PFCs | SF6 | Other halogenated gases with CO2 equivalent conversion factors (1) | Other halogenated gases without CO2 equivalent conversion factors (2) | NOx | CO | NMVOCs | SO2 |
| 2.G.1 - Electrical Equipment | NA | NA | NA | NA | NE | 0.000 | NA | NE | 0.000 | 0.000 | 0.000 | 0.000 |
| 2.G.1.a - Manufacture of Electrical Equipment | NA | NA | NA | NA | NO | NO | NA | NO | NA | NA | NA | NA |
| 2.G.1.b - Use of Electrical Equipment | NA | NA | NA | NA | NE | NE | NA | NE | NA | NA | NA | NA |
| 2.G.1.c - Disposal of Electrical Equipment | NA | NA | NA | NA | NE | NE | NA | NE | NA | NA | NA | NA |
| 2.G.2 - SF6 and PFCs from Other Product Uses | NA | NA | NA | NA | NE | NE | NA | NE | NA | NA | NA | NA |
| 2.G.2.a - Military Applications | NA | NA | NA | NA | NE | NE | NA | NE | NA | NA | NA | NA |
| 2.G.2.b - Accelerators | NA | NA | NA | NA | NE | NE | NA | NE | NA | NA | NA | NA |
| 2.G.2.c - Other (please specify) (3) | NA | NA | NA | NA | NO | NO | NA | NO | NA | NA | NA | NA |
| 2.G.3 - N2O from Product Uses | NA | NA | 0.008 | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 2.G.3.a - Medical Applications | NA | NA | NE | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 2.G.3.b - Propellant for pressure and aerosol products | NA | NA | NO | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 2.G.3.c - Other (Please specify) (3) | NA | NA | 0.008 | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 2.G.4 - Other (Please specify) (3) | NA | NA | NO | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **2.H - Other** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.278 | 0.000 |
| 2.H.1 - Pulp and Paper Industry | NO | NO | NA | NA | NA | NA | NA | NA | NO | NO | NO | NO |
| 2.H.2 - Food and Beverages Industry | 0.000 | 0.000 | NA | NA | NA | NA | NA | NA | 0.000 | 0.000 | 1.278 | 0.000 |
| 2.H.3 - Other (please specify) (3) | NO | NO | NO | NA | NA | NA | NA | NA | NO | NO | NO | NO |

# 6. Agriculture, Forestry and Other Land Use (AFOLU)

## 6.1. Description of AFOLU sector

The AFOLU sector includes activities responsible for GHG emissions and removals linked to Agriculture (crops and livestock), changes in land use within and between the six IPCC land use classes, soil organic matter dynamics, fertilizer use and management of land. Emissions and removals were estimated for activity areas falling under all four IPCC categories of this sector.

New CS emission and stock factors were derived for the country and for the livestock and land categories. A different set of criteria was adopted to better represent the land classes within the national context since the basis adopted until the previous inventory was no longer representative of the situation of the country.

Namibia provides for a diversity of activities in the AFOLU sector occurring at varying intensities. Commercial and communal systems of production in the livestock and crop sectors are both present. Land use changes due to human activities mainly in forestland, woodland, grassland and cropland were significant contributors to emissions while also acting as sinks, particularly through the phenomenon of bush-encroachment.

### 6.1.1. Emission estimates for the AFOLU sector

The AFOLU sector remained a sink throughout the timeseries. Net removals increased from 71,540 Gg $CO_2$-eq in the year 1990 to 109,787 in the year 2016. There was a 40% increase in emissions from the livestock category. Emissions from aggregate sources and non-$CO_2$ emissions from land varied from 2,881 Gg $CO_2$-eq to 6,702 Gg $CO_2$-eq. The variation in this sub-category was directly linked to the land area (biomass) burned. The land sub-category removal of 81,286 Gg $CO_2$ in 1990 reached 116,829 Gg in 2016 (Table 6.1).

**Table 6.1 - Aggregated emissions ($CO_2$-eq) from the AFOLU sector (1990 - 2016)**

| Year | 3 - Agriculture, Forestry, and Other Land Use | 3.A - Livestock | 3.B - Land | 3.C - Aggregate sources and non-$CO_2$ emissions sources on land | 3.D Harvested Wood Products |
|---|---|---|---|---|---|
| 1990 | -71,540 | 3,043 | -81,286 | 6,702 | 0 |
| 1991 | -73,316 | 3,204 | -83,059 | 6,538 | 0 |
| 1992 | -75,586 | 3,133 | -84,971 | 6,252 | 0 |
| 1993 | -77,893 | 2,935 | -86,753 | 5,925 | 0 |
| 1994 | -79,960 | 2,908 | -88,553 | 5,685 | 0 |
| 1995 | -81,922 | 2,946 | -90,370 | 5,502 | 0 |
| 1996 | -84,163 | 2,846 | -92,205 | 5,196 | 0 |
| 1997 | -86,067 | 2,964 | -94,057 | 5,026 | 0 |
| 1998 | -88,212 | 3,070 | -95,927 | 4,828 | -183 |
| 1999 | -90,197 | 3,179 | -97,814 | 4,636 | -199 |
| 2000 | -92,130 | 3,467 | -100,023 | 4,476 | -50 |
| 2001 | -92,164 | 3,470 | -99,969 | 4,510 | -176 |
| 2002 | -97,252 | 3,338 | -104,418 | 3,789 | 39 |
| 2003 | -97,648 | 3,393 | -104,835 | 3,837 | -43 |

| Year | 3 - Agriculture, Forestry, and Other Land Use | 3.A - Livestock | 3.B - Land | 3.C - Aggregate sources and non-$CO_2$ emissions sources on land | 3.D Harvested Wood Products |
|---|---|---|---|---|---|
| 2004 | -99,719 | 3,350 | -106,631 | 3,583 | -21 |
| 2005 | -97,274 | 3,180 | -104,375 | 3,969 | -47 |
| 2006 | -92,745 | 3,340 | -100,749 | 4,718 | -54 |
| 2007 | -89,556 | 3,289 | -97,959 | 5,179 | -66 |
| 2008 | -99,302 | 3,388 | -106,554 | 3,921 | -58 |
| 2009 | -85,484 | 3,346 | -94,677 | 5,997 | -150 |
| 2010 | -90,555 | 3,153 | -98,888 | 5,265 | -86 |
| 2011 | -86,675 | 3,718 | -96,111 | 5,840 | -122 |
| 2012 | -85,146 | 3,961 | -95,162 | 6,145 | -91 |
| 2013 | -106,610 | 3,566 | -113,048 | 2,957 | -85 |
| 2014 | -102,736 | 3,879 | -110,138 | 3,622 | -100 |
| 2015 | -105,222 | 3,775 | -112,223 | 3,312 | -86 |
| 2016 | -109,787 | 4,252 | -116,829 | 2,881 | -90 |

Table 6.2 shows the evolution in emissions of the direct and indirect GHGs. $CO_2$ emissions increased steadily from 8,736 Gg in 1990 to reach 9,770 Gg in 2016. However, $CO_2$ removals far exceeded emissions over the whole period with an increasing trend. Removals increased from 90,021 Gg in 1990 to 126,688 Gg in 2016. The other two direct gases $CH_4$ and $N_2O$ varied over the inventory period on account of the annual variation in the area burnt in forestland and grassland, outcome of wildfires over the country. $CH_4$ emissions ranged from 227 Gg to 318 Gg while $N_2O$ emissions were between 7.4 Gg and 11.0 Gg.

Emissions of the indirect gases and NMVOCs also varied over the inventory period for the same reason as for $CH_4$ and $N_2O$. $NO_x$ emissions varied between 5.4 Gg and 41.4 Gg, CO between 349 Gg and 2,627 Gg and NMVOCs between 9.0 Gg and 13.5 Gg. Emissions of $CH_4$, $N_2O$, $NO_x$ and CO regressed during the inventory period since the area burnt in forestland and grassland significantly decreased because of improved management.

**Table 6.2 - Emissions (Gg) by gas for AFOLU (1990 - 2016)**

| Year | $CO_2$ - Emissions | $CO_2$ - Removals | $CO_2$ - Net removals | $CH_4$ | $N_2O$ | $NO_x$ | CO | NMVOCs |
|---|---|---|---|---|---|---|---|---|
| 1990 | 8,736 | -90,021 | -81,286 | 311 | 10.0 | 41.4 | 2,627 | 9.5 |
| 1991 | 8,736 | -91,794 | -83,058 | 311 | 10.4 | 39.5 | 2,505 | 10.0 |
| 1992 | 8,736 | -93,706 | -84,970 | 299 | 10.0 | 37.5 | 2,383 | 9.8 |
| 1993 | 8,736 | -95,488 | -86,753 | 283 | 9.4 | 35.7 | 2,268 | 9.2 |
| 1994 | 8,736 | -97,288 | -88,552 | 274 | 9.2 | 33.8 | 2,152 | 9.2 |
| 1995 | 8,736 | -99,105 | -90,370 | 269 | 9.0 | 32.0 | 2,035 | 9.1 |
| 1996 | 8,736 | -100,940 | -92,205 | 256 | 8.6 | 30.1 | 1,917 | 9.0 |
| 1997 | 8,736 | -102,793 | -94,057 | 254 | 8.6 | 28.2 | 1,798 | 9.3 |
| 1998 | 8,736 | -104,845 | -96,109 | 251 | 8.5 | 26.3 | 1,678 | 9.7 |
| 1999 | 8,735 | -106,748 | -98,013 | 248 | 8.4 | 24.4 | 1,557 | 10.0 |
| 2000 | 8,736 | -108,809 | -100,073 | 251 | 8.6 | 22.1 | 1,408 | 11.0 |
| 2001 | 8,949 | -109,091 | -100,142 | 252 | 8.7 | 22.2 | 1,419 | 10.9 |
| 2002 | 8,988 | -113,365 | -104,377 | 224 | 7.8 | 16.8 | 1,073 | 10.5 |
| 2003 | 8,947 | -113,824 | -104,877 | 227 | 8.0 | 16.8 | 1,076 | 10.6 |

| Year | $CO_2$ - Emissions | $CO_2$ - Removals | $CO_2$ - Net removals | $CH_4$ | $N_2O$ | $NO_x$ | CO | NMVOCs |
|---|---|---|---|---|---|---|---|---|
| 2004 | 8,947 | -115,598 | -106,651 | 217 | 7.7 | 14.9 | 957 | 10.6 |
| 2005 | 8,947 | -113,368 | -104,422 | 224 | 7.9 | 18.7 | 1,197 | 10.1 |
| 2006 | 8,947 | -109,749 | -100,803 | 254 | 8.8 | 24.1 | 1,546 | 10.7 |
| 2007 | 8,947 | -106,971 | -98,024 | 267 | 9.3 | 28.5 | 1,829 | 10.5 |
| 2008 | 8,946 | -115,558 | -106,612 | 229 | 8.0 | 17.6 | 1,130 | 10.8 |
| 2009 | 8,947 | -103,774 | -94,827 | 297 | 10.1 | 34.1 | 2,190 | 10.7 |
| 2010 | 8,947 | -107,920 | -98,973 | 266 | 9.1 | 29.1 | 1,868 | 10.3 |
| 2011 | 9,769 | -106,002 | -96,233 | 301 | 10.4 | 31.2 | 2,003 | 11.7 |
| 2012 | 9,769 | -105,021 | -95,252 | 318 | 11.0 | 32.5 | 2,091 | 12.5 |
| 2013 | 9,769 | -122,901 | -113,132 | 202 | 7.4 | 9.1 | 582 | 11.3 |
| 2014 | 9,769 | -120,007 | -110,238 | 234 | 8.3 | 13.3 | 858 | 12.6 |
| 2015 | 9,769 | -122,078 | -112,309 | 219 | 8.0 | 11.0 | 705 | 12.2 |
| 2016 | 9,770 | -126,688 | -116,918 | 218 | 8.3 | 5.4 | 349 | 13.5 |

The evolution of aggregated emissions, excluding removals, of the three direct GHGs is presented in Figure 6.1. Total emissions fluctuated between 12,650 Gg $CO_2$-eq and 19,875 Gg $CO_2$-eq during the period 1990 to 2016, with the peak occurring in 2012. Emissions of the three direct GHGs varied during the inventory period. The major contributor to emissions remained $CO_2$ contributing on average 53% of total emissions for this period in this sector followed by $CH_4$ with an average of 31% and $N_2O$ the remaining 16%.

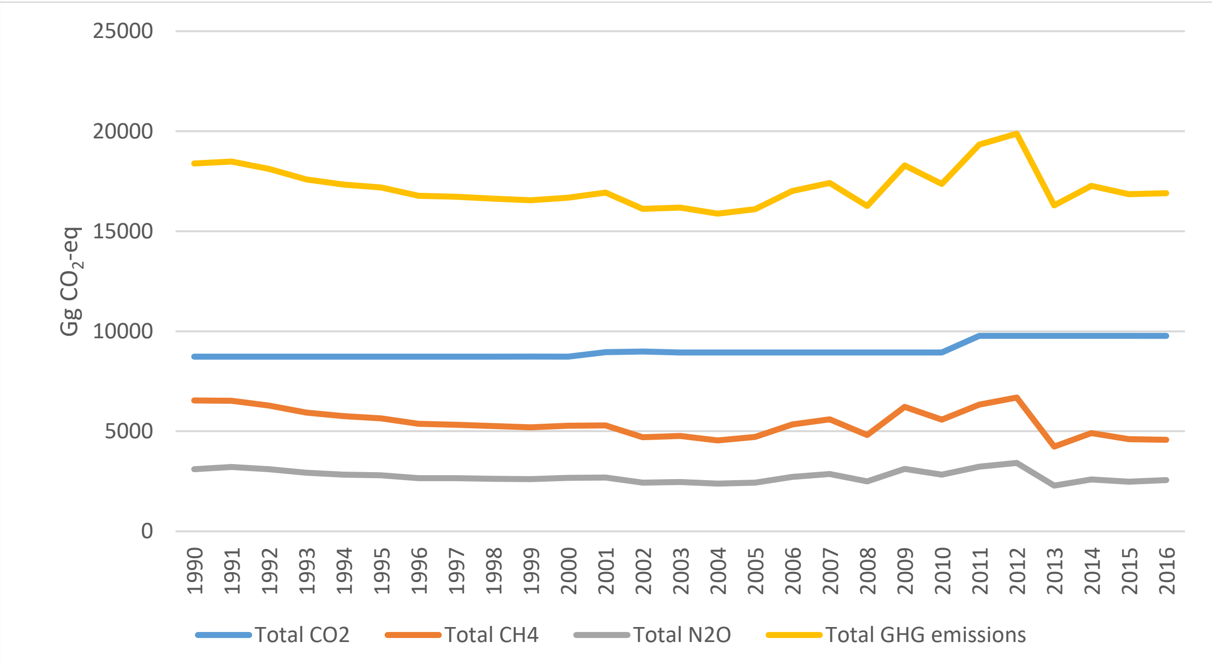


**Figure 6.1- Evolution of aggregated emissions ($CO_2$-eq) in the AFOLU sector (1990 - 2016)**

## 6.2. Livestock

Namibia has an important livestock rearing activity because of its dry climate and extensive grazing areas available. The major livestock is cattle, including dairy cows followed by the smaller ruminants, goats and sheep. The management conditions differ between the commercial and communal systems of livestock rearing. An increased production in the poultry sub-category occurred during 2014 with the setting up of commercial intensive farms.

## 6.3. Methods

Tier 2 level has been adopted for cattle and dairy cows for enteric fermentation while Tier 1 was used for manure management. A Tier 1 approach was adopted for all other animals. Available CS data on live weight, pregnancy and other parameters were collected and used. Missing data were generated as described in the EF section later in this chapter.

### 6.3.1. Activity Data

#### 6.3.1.1. Source

The FAO database together with information from the NSA and annual surveys done by the Ministry of Agriculture were used. Priority was given to country data over the international database. Where local statistics were not available, data from the FAO database was used.

#### 6.3.1.2. Quality control / Quality Assurance

Due to the importance of this sector in the socio-economic context of the country, the livestock population is tracked meticulously to maintain a healthy sanitary status and avoid disease spread. All new-borns and animals culled or exported are followed through a tagging system managed by the national veterinary services of the MAWF. Thus, local data were privileged and considered of good quality and the few missing data points were generated using statistical modelling techniques, interpolation or trend analysis. In fact, national data corresponded with those of the FAO database for most of the years except where the latter organisation resorted to estimations.

#### 6.3.1.3. Removal of outliers

There were two outliers that were replaced using interpolation or trend analysis. Furthermore, in the case of camels, the figures prior to 1999 for the FAO database were not used even though the local statistics were not available as the information obtained was that these animals were introduced in the country in the year 2000 for the tourist activity.

#### 6.3.1.4. Animal population

The population of the different livestock types used as AD for estimating emission is provided in Table 6.3 for the years 1990 to 2016.

To move to Tier 2 estimates, it is essential to segregate the population into sub-divisions according to age, sex, and gender. The cattle population recorded for both the commercial and communal sectors was further sub-divided into mature bulls, mature females, mature male castrates, young intact males and young females following a split of respectively 36%, 4%, 16%, 20% and 24% based on a study on farming practices (NNFU, 2006). The sub-division into the different classes was available for communal animals only. The same split was adopted for the commercial sector as this is the normal situation for cattle rearing.

Table 6.3 - Number of animals (1990 - 2016)

| Year | Dairy cows | Cattle | Sheep | Goats | Horses | Mules and asses | Swine | Poultry | Camels |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 1,500 | 2,086,551 | 3,328,316 | 1,859,748 | 52,054 | 68,000 | 17,865 | 508,242 | 0 |
| 1991 | 1,500 | 2,211,624 | 3,295,447 | 1,991,581 | 51,000 | 68,000 | 16,904 | 502,667 | 0 |
| 1992 | 1,500 | 2,206,373 | 2,863,401 | 1,750,238 | 54,540 | 70,000 | 14,790 | 497,092 | 0 |
| 1993 | 1,500 | 2,073,540 | 2,651,823 | 1,579,856 | 57,391 | 85,000 | 20,065 | 491,518 | 0 |
| 1994 | 1,500 | 2,035,790 | 2,619,520 | 1,639,210 | 58,801 | 145,607 | 17,843 | 464,451 | 0 |
| 1995 | 1,500 | 2,031,353 | 2,409,699 | 1,616,090 | 53,217 | 145,607 | 19,979 | 487,031 | 0 |
| 1996 | 1,500 | 1,989,947 | 2,198,436 | 1,786,150 | 53,217 | 145,607 | 18,923 | 458,158 | 0 |
| 1997 | 1,500 | 2,055,416 | 2,429,328 | 1,821,009 | 53,217 | 145,607 | 16,884 | 522,618 | 0 |
| 1998 | 1,500 | 2,192,359 | 2,086,434 | 1,710,190 | 53,217 | 145,607 | 14,706 | 403,937 | 0 |
| 1999 | 1,500 | 2,278,569 | 2,169,651 | 1,689,770 | 53,217 | 145,607 | 18,731 | 450,513 | 0 |
| 2000 | 1,500 | 2,504,930 | 2,446,146 | 1,849,569 | 61,885 | 167,548 | 23,148 | 476,331 | 54 |
| 2001 | 1,500 | 2,508,570 | 2,369,809 | 1,769,055 | 52,502 | 169,314 | 21,854 | 502,356 | 71 |
| 2002 | 1,500 | 2,329,553 | 2,764,253 | 2,110,092 | 47,220 | 134,305 | 47,805 | 883,950 | 88 |
| 2003 | 1,500 | 2,336,094 | 2,955,454 | 2,086,812 | 47,542 | 119,828 | 46,932 | 894,027 | 124 |
| 2004 | 1,500 | 2,349,700 | 2,619,363 | 1,997,172 | 62,726 | 142,353 | 52,624 | 957,966 | 113 |
| 2005 | 1,500 | 2,219,330 | 2,663,795 | 2,043,479 | 47,429 | 140,291 | 55,931 | 998,278 | 63 |
| 2006 | 1,500 | 2,383,960 | 2,660,252 | 2,061,403 | 46,209 | 159,948 | 51,972 | 923,555 | 73 |
| 2007 | 1,500 | 2,353,498 | 2,652,658 | 1,926,429 | 43,863 | 156,328 | 51,863 | 916,991 | 63 |
| 2008 | 1,500 | 2,453,097 | 2,228,059 | 1,893,387 | 42,267 | 165,126 | 49,187 | 864,988 | 43 |
| 2009 | 1,500 | 2,465,989 | 1,803,460 | 1,792,390 | 38,201 | 173,923 | 48,223 | 843,277 | 23 |
| 2010 | 1,500 | 2,389,891 | 1,378,861 | 1,690,467 | 49,852 | 141,588 | 63,498 | 777,480 | 43 |
| 2011 | 1,500 | 2,762,240 | 2,209,593 | 1,736,565 | 45,529 | 105,062 | 43,865 | 684,236 | 69 |
| 2012 | 1,500 | 2,904,451 | 2,677,913 | 1,933,103 | 46,643 | 114,591 | 69,430 | 940,765 | 47 |
| 2013 | 2,000 | 2,634,418 | 2,188,758 | 1,693,145 | 40,265 | 124,120 | 69,070 | 659,033 | 51 |
| 2014 | 2,000 | 2,882,489 | 2,044,156 | 1,892,439 | 55,241 | 159,029 | 68,710 | 3,436,430 | 55 |
| 2015 | 2,000 | 2,808,117 | 1,973,393 | 1,868,535 | 47,151 | 148,859 | 62,945 | 2,429,529 | 37 |
| 2016 | 2,000 | 3,173,767 | 1,746,642 | 1,968,513 | 40,708 | 144,647 | 83,191 | 2,786,182 | 12 |

The average live weights of the non-dairy cattle classes were obtained from data of the slaughterhouses of MeatCo and auction of livestock. Information on development and typical animal mass of the dominant local breeds Brahman and Nguni were used. Daily weight gain was derived from the live weight and age of the different animal groups at slaughtering or auction time. The data was compared and aligned with information obtained from breeding studies done on the 2 main species with various others (S.J. Schoeman, 1996). The live weight for dairy cows has been assumed to be 525 kg based on available information on the race, awaiting confirmation of the current liveweight of the population from the dairy farms.

For Tier 2 estimations, it is also necessary to assign a typical mature weight for each animal group and these values for commercial and communal cattle classes were again derived from the weight of animals slaughtered or sold at auctions. Table 6.4 depicts the typical mature weight adopted for the different classes.

Table 6.4 - Typical animal mass

| Animal type | Description | Typical mass or mature weight (Kg) |
|---|---|---|
| Dairy cow | | 525 |
| Commercial cattle | Mature males | 506 |
| | Mature female | 480 |
| | Mature male castrate | 506 |
| | Young growing male | 251 |
| | Young growing female | 251 |
| Communal cattle | Mature males | 435 |
| | Mature female | 323 |
| | Mature male castrate | 403 |
| | Young intact male | 146 |
| | Young growing female | 146 |
| Other animals | Sheep | 34.9 |
| | Goats | 30 |
| | Horses | 238 |
| | Mules and asses | 130 |
| | Swine | 28 |
| | Poultry | 1.8 |
| | Camels | 217 |

### 6.3.2. Emission factors

Management practices adopted for livestock have an important impact in determining the level of emissions. Both enteric fermentation and manure management EFs are dependent of such practices, namely the feeding situation, daily work performed, lactation period and frequency of pregnancy and the management of the excreta. Since emissions of enteric fermentation fell in the key categories in previous inventories, a Tier 2 approach has been maintained for this category. For the other animal groups, the default EFs (2006 IPCC GL, Table 10-10, p. 1.28, developing countries) have been used to compute enteric fermentation and manure management $CH_4$ emissions.

Country specific EFs were derived for enteric fermentation using country data and information in the equations provided for this exercise in the 2006 IPCC GL for most of the animal classes. The datasets described above were used to calculate the maximum methane production capacity for the cattle classes while default EFs from the IPCC 2006 Guidelines were used for the other animal groups. Methane Correction Factor (MCF) default EFs were used for animal classes as per Table 6.5.

Table 6.5 - MCF values used for computing enteric fermentation emissions

| Animal type | Description | MCF (Kg $CH_4$/head/yr) |
|---|---|---|
| Dairy cow | | 92 |
| Commercial cattle | Mature males | 69 |
| | Mature female | 70 |
| | Mature male castrate | 72 |
| | Young growing male | 59 |

| Animal type | Description | MCF (Kg $CH_4$/head/yr) |
|---|---|---|
| | Young growing female | 66 |
| Communal cattle | Mature males | 59 |
| | Mature female | 46 |
| | Mature male castrate | 55 |
| | Young intact male | 36 |
| | Young growing female | 40 |
| Other animals | Sheep | 5 |
| | Goats | 5 |
| | Horses | 18 |
| | Mules and asses | 10 |
| | Swine | 1 |
| | Camels | 46 |

Table 6.6 summarizes the manure management systems (MMSs) for the various animal categories. This is based on information available from the censuses and surveys conducted by the MAWF and NSA while MMS for cattle are based on expert judgment and on information from the farming systems guide (NNFU, 2006). Experts comprised officers of the MAWF, commercial livestock herders and communal farmers. As manure management is not a key category for all animal classes, the default EFs from the guidelines were adopted.

The temperature assigned for this sub-category for Namibia in inventories prior to 2018 was 26°C and this was amended to 20°C as from 2019 as it was a mistake. In fact, Namibia falls under a temperate climate according to the IPCC Guideline except for small area classified as Tropical Dry and temperature cannot be 26°C. This is confirmed from processing of data available on the site http://sdwebx.worldbank.org/climateportal/index.cfm?page=country_historical_climate&ThisCCode=NAM for the period 1901 to 2015.

**Table 6.6 - MMS adopted for the different animal categories**

| Type of animal | Manure management system |
|---|---|
| Dairy cows | Solid storage |
| Commercial cattle (All) | 100% Pasture-Range-Paddock (PRP) |
| Communal cattle (All) | 50% PRP/ 49% Solid Storage / 1% Burnt for fuel |
| Sheep | 100% PRP |
| Goats | PRP 100% |
| Horses | 100% PRP |
| Mules and asses | 100% PRP |
| Swine | Daily spread 60% and liquid slurry 40% |
| Poultry | Poultry manure with litter 60% and poultry manure without litter 40% |
| Camels | 100% PRP |

Pregnancy has been accounted for dairy, commercial and communal cows. The lactation period of dairy cows is zero day as the calves are severed just after birth. Lactation by commercial and communal cows have not been integrated in the derivation of the MCFs due to inadequacy of available information. This improvement has been included in the NIIP.

The digestible energy is taken from the 2006 IPCC GL, Chapter 10, annex Table 10A2 for animals in large grazing areas except for dairy cows for which the factor of 75% for feedlot cattle has been adopted.

The average daily work for commercial and communal cattle has been assumed as 6 hours/day for the whole year, based on expert judgment of members of the Namibian GHG inventory team for mature male castrates only, as the other animal groups do not perform any work. This is being verified for action in the next inventory.

## 6.4. Results - Emission estimates

The emission estimates from enteric fermentation and manure management are presented in Table 6.7. Enteric fermentation contributed more than 94% of total emissions of $CH_4$ from the livestock category during the whole time series. Emissions increased from 2,878 Gg $CO_2$-eq in 1990 to 4,000 Gg $CO_2$-eq in 2016. The main contributor to the substantial increase as from 2011 is the further development of the dairy industry with an increase in the number of dairy cows from 1,500 to 2,000 and a gradual increase in the population of other cattle from about 2.1 M to 2.8 M during the same period. Emissions from manure management increased from 165 Gg $CO_2$-eq to 252 Gg $CO_2$-eq in 2016 as the manure management practice did not change much over the inventory period.

**Table 6.7 - Emissions (Gg $CO_2$-eq) from enteric fermentation and manure management of livestock (1990 - 2016)**

| Year | Enteric Fermentation | Manure management |
|---|---|---|
| 1990 | 2,878.1 | 165.4 |
| 1991 | 3,029.8 | 174.3 |
| 1992 | 2,960.7 | 172.2 |
| 1993 | 2,772.8 | 161.9 |
| 1994 | 2,747.3 | 160.6 |
| 1995 | 2,793.9 | 152.0 |
| 1996 | 2,687.2 | 159.0 |
| 1997 | 2,800.9 | 163.1 |
| 1998 | 2,898.1 | 171.6 |
| 1999 | 2,998.4 | 181.0 |
| 2000 | 3,263.8 | 203.3 |
| 2001 | 3,272.7 | 197.5 |
| 2002 | 3,150.0 | 187.6 |
| 2003 | 3,210.3 | 182.2 |
| 2004 | 3,163.0 | 187.4 |
| 2005 | 2,997.6 | 182.1 |
| 2006 | 3,138.6 | 201.6 |
| 2007 | 3,091.8 | 197.5 |
| 2008 | 3,191.4 | 196.6 |

| Year | Enteric Fermentation | Manure management |
|---|---|---|
| 2009 | 3,150.7 | 195.2 |
| 2010 | 2,957.7 | 195.8 |
| 2011 | 3,502.3 | 215.4 |
| 2012 | 3,731.8 | 229.6 |
| 2013 | 3,358.1 | 207.6 |
| 2014 | 3,650.3 | 229.1 |
| 2015 | 3,553.1 | 221.8 |
| 2016 | 3,999.6 | 252.0 |

The evolution of emissions of the three gases $CH_4$, $N_2O$ and NMVOCs emitted by the Livestock category is given in Table 6.8. There is an increase in emissions for all three 3 gases from 1990 to 2016. The increase over this period was of the order of 55 Gg (39%) for $CH_4$, 0.18 Gg for (57%) for $N_2O$ and 4.0 Gg (43%) for NMVOCs, respectively.

**Table 6.8 - Emissions (Gg) by gas for Livestock (1990-2016)**

| Year | $CH_4$ | $N_2O$ | NMVOCs |
|---|---|---|---|
| 1990 | 140.1 | 0.325 | 9.5 |
| 1991 | 147.5 | 0.344 | 10.0 |
| 1992 | 144.1 | 0.344 | 9.8 |
| 1993 | 135.0 | 0.323 | 9.2 |
| 1994 | 133.8 | 0.317 | 9.2 |
| 1995 | 136.2 | 0.276 | 9.1 |
| 1996 | 131.1 | 0.300 | 9.0 |
| 1997 | 136.7 | 0.304 | 9.3 |
| 1998 | 141.3 | 0.329 | 9.7 |
| 1999 | 146.3 | 0.348 | 10.0 |
| 2000 | 159.2 | 0.400 | 11.0 |
| 2001 | 159.6 | 0.384 | 10.9 |
| 2002 | 153.7 | 0.355 | 10.5 |
| 2003 | 156.6 | 0.337 | 10.6 |
| 2004 | 154.3 | 0.353 | 10.6 |
| 2005 | 146.3 | 0.346 | 10.1 |
| 2006 | 153.2 | 0.396 | 10.7 |
| 2007 | 150.9 | 0.388 | 10.5 |
| 2008 | 155.7 | 0.385 | 10.8 |
| 2009 | 153.6 | 0.387 | 10.7 |
| 2010 | 144.2 | 0.401 | 10.3 |
| 2011 | 170.7 | 0.432 | 11.7 |
| 2012 | 181.9 | 0.456 | 12.5 |
| 2013 | 163.7 | 0.414 | 11.3 |
| 2014 | 178.0 | 0.455 | 12.6 |
| 2015 | 173.2 | 0.442 | 12.2 |
| 2016 | 194.9 | 0.511 | 13.5 |

## 6.5. Land

All lands within the Namibian territory have been classified under the six IPCC land categories and have been treated in this inventory as managed land. Thus, they have all been accounted for in the compilation of emissions and removals. Activities within the six IPCC land classes and between the classes were taken into consideration. Land use changes has been derived from the land cover maps generated from satellite imagery, more fully described below under land representation and changes.

The six land categories are:

- 3.B.1 Forestland
- 3.B.2 Cropland
- 3.B.3 Grassland
- 3.B.4 Wetlands
- 3.B.5 Settlements
- 3.B.6 Other land

### 6.5.1. Description

#### 6.5.1.1. Forestland

Forests were divided in two sub-categories and the definitions adopted for the integration of all information from FRA (Global Forest Resources Assessment 2010), RCMRD (Regional Centre for Mapping Resource for Development ) maps and other reports are provided below:

- Forestland (FL): tree height of 5 m and a canopy cover of more than 20%; and
- Other Wooded Land (OWL): The are three different land classes in this sub-category:
  - Woodlands: where tree height of 5 m with a canopy cover between 10% and 20% are present.
  - Shrubland: where trees and saplings are present as these have been invaded long ago and trees have grown to a height whereby some areas can now be reclassified as woodland or forest.
  - Savannah grassland: where bush invasion is occurring with an increase in woody biomass.

A major change as from the NIR3 is the reclassification and merger of the bush-encroached grassland with the degraded woodlands of Namibia to form the Other Wooded Land sub-class in Forestland. This approach has been adopted as the IPCC Inventory Software does not estimate woody biomass changes in Grasslands and most of the activity on woody biomass removals occur in this land class.

#### 6.5.1.2. Cropland

Land used for annual cropping has been considered. The main crops are maize, wheat and millet and sorghum produced under both commercial and communal systems. It is estimated that not all land cleared for growing crops are used every year.

#### 6.5.1.3. Grassland

Grassland is now redefined as a pure stand without the presence of woody biomass as in the last NIR. The area of grassland is estimated to be situated between the bush encroachment wetter Northern part of the country and the desert found on the South Western part.

#### 6.5.1.4. Wetlands

Water bodies, rivers and other marshy areas are considered as Wetlands. The area of this land class has been kept fixed as no development has been done on Wetlands during the inventory period.

#### 6.5.1.5. Settlements

Land with infrastructures such as roads, buildings, houses and other man-made structures have been included under Settlements. Urbanization and development of the road network are the major contributors to change in this land class.

#### 6.5.1.6. Other Land

All other land present in Namibia and not falling in any of the above categories are included under this category. Desert, rock outcrops and bare land are the main constituents of Other Land. There was no change in this land class during the timeseries.

### 6.5.2. Methods

Estimation of emissions by source and removals by sink for the Land sector has been done using Approach 2 with a mix of Tier 1 and Tier 2 levels. The latter has been applied for the categories falling under Land as some of these were key sources in the last inventory. Most of the stock factors have been derived using data from past forest inventories and other available in-country information and resources.

### 6.5.3. Activity Data

#### 6.5.3.1. Land representation and changes

A new rationale for compiling the GHG inventory in the Land category was used. Deforestation was a fact during the past century when tree felling was an economic activity for timber production. Furthermore, other human activities such as fuelwood collection, construction of dwellings, fencing, crafts and arts have contributed to the state of degradation of the remaining Forestland and OWL.

Several reports and studies show that Namibia has witnessed a constant woody biomass accumulation in its Forestland and OWL from natural regeneration and more rapidly from the phenomenon of encroachment by both indigenous and alien species. Invasion by indigenous and exotic species have been observed since a century and have accelerated in the past 3 decades to become a serious problem, especially when the encroachment has been on the grasslands. Invasion is so much an issue that some areas are completely colonised with these encroacher species while others are affected to a lesser degree, but the result is that the carrying capacity of the rangelands of the country has decreased to a point which is menacing the sustainability of the livestock industry. In fact, there is a programme for rehabilitating the rangelands which is presently ongoing.

Thus, deforestation as reported in the FRA of FAO is considered not representative of the national circumstances. In fact, FAO worked on information from different sources to generate land cover and land use for the year 2000 and adopted a rate of deforestation with linear extrapolation for the years 2005, 2010, 2015 and back to 1990. In the FRA reports, reclassification of various land cover types with vegetation does not allow the capture of movement in land use changes happening as per national circumstances. Table 6.9 below shows the reclassification done by FAO. It is not clear from the FRA reports on which basis FAO arrived at the three classes of land, Forests, OWL and especially Other Land. These three classes do not fit the IPCC land representation and reporting requirements. However, this classification has been partly used as explained later to support the generation of land use changes.

**Table 6.9 - Reclassification of various land classes into 3 main classes done in FRA for year 2000**

| Land cover description | Calibrated area in FRA 2000 (ha) | Calibrated area reclassified under new class | | |
|---|---|---|---|---|
| | | Forests | OWL | OL |
| Shrubland | 43,460,321 | - | - | 43,460,321 |
| Forest | 99,496 | 99,496 | - | - |
| Grassland | 7,220,148 | - | - | 7,220,148 |
| Riverine woodland | 346,870 | 208,122 | 104,061 | 34,687 |
| Salt pans | 538,262 | - | - | 538,262 |
| Shrubland-Woodland mosaic | 14,211,507 | - | 4,689,797 | 9,521,710 |
| Sparse grassland and Shrubland | 3,576,921 | - | - | 3,576,921 |
| Woodland | 12,875,475 | 7,725,285 | 3,862,643 | 1,287,548 |
| Total | 82,329,000 | 8,032,903 | 8,656,501 | 65,639,596 |

Data from maps produced by RCMRD were used for generating land use changes for previous NIRs. A summary of the original data is shown in Table 6.10. Explanations of the problems encountered with the original data is provided in the previous NIRs accessible from the UNFCCC website. The change in land cover from the time series were not sustainable and differed a lot from those adopted in the FRA reports. The major problem areas were:

- Unsustainable deforestation rates that would result in the Forestland and Woodland disappearing in the medium term.
- Non-realistic land use changes recorded such as Settlements being converted to Forest
- Inclusion of vast areas with significant stocks of woody biomass under Grassland
- The area of Other Land double that of previous studies and reports.

Namibia is an arid country and the use of satellite imagery to track land cover and land use change can be misleading if not done with care and at the appropriate period of the year. For example, an image of land with woody biomass can be interpreted as being grassland/shrubland if that image has been taken during the dry season as opposed the rainy season as the canopy cover will be very different. Additionally, ground truthing of the maps was done on a restricted basis due to lack of resources.

**Table 6.10 - Summary of original RCMRD Land Use Cover derived from satellite imagery**

| Land cover type | Year 2000 (ha) | Year 2010 (ha) |
|---|---|---|
| Cropland | 625,001 | 501,879 |
| Forestland | 2,942,075 | 1,969,215 |
| Woodland | 924,510 | 271,436 |
| Grassland | 7,393,363 | 3,984,627 |
| Savannah grassland | 36,911,447 | 37,229,582 |
| Shrubland | 7,397,053 | 15,400,213 |
| Other land | 25,612,829 | 22,302,300 |
| Settlements | 29,896 | 38,863 |
| Wetland | 724,608 | 862,667 |

Due to these inconsistencies, it was felt necessary to review the situation, consider all available information and work out improved land use changes. The description of each land class among the various documents (FRA, RCMRD, Atlas of Namibia etc.) had inherent differences and overlaps in their coverage. The information was merged with the objective meeting the requirements of the IPCC land categories. The merger also had to integrate information available with respect to bush encroachment and its related debushing activities.

Forestland areas for 2000 and 2010 were adopted from FRA. The area of Settlements with its changes were taken from the RCMRD maps. The different areas between woodland, shrubland and savannah grassland was a mix of information from RCMRD and FRA. Cropland and Wetland areas were taken from RCMRD maps. The extent of Other Land was the remainder after distracting the other classes from the area of the territory. This was in line with the area classified as Other Land in Atlas of Namibia (Mendelsohn, et al., 2002)

#### 6.5.3.2. Changes

***Forestland***

***Deforestation***

Deforestation is estimated to be under control since the independence of Namibia. Various laws and regulations have helped to preserve the remaining Forestland of the country. A rise in the standard of living and urbanization has decreased the pressure for wood resources from forests. A gain of 10,000 ha yearly from OWL has been included on account of bush encroachment since the 1960s. On account of the thickness of the bush as well as the fact that it has reached more than 5 metres, the change in its classification was warranted.

De-bushing methods include the use of chemicals and other mechanical means to get rid of the trees that are affecting farms, particularly with respect to carrying capacity of livestock. It is reported that 80,000 hectares were de-bushed annually during the 1990s (Routhauge A., 2014). The use of chemicals for bush control is being discouraged by the authorities. This rate increased to 90,000 hectares during the first decade of the 21st century and 100,000 hectares as from 2011 (De Klerk J.N., 2004). Added to that, an NGO (Non-Governmental Organization), the Cheetah Foundation has implemented a project on the rehabilitation of the natural habitat of the cheetah, a threatened species because of bush encroachment. This activity produced some 8,000 tonnes of bush-block annually (Feller S. et al., 2006) from the encroached species. They are sold or exported, and the proceeds used to support the project financially.

Encroachment has nearly peaked as the Grassland are in the drier environment with rainfall inadequate to support growth of bushes and trees eventually. The aim now is to keep the right balance for economic activities to be sustainable, preserving the ecosystems and biodiversity through the control of encroachment by harvesting bush species for use as woody biomass feedstocks.

Since independence, the Government of Namibia has promulgated many forests as protected areas, conservancies and community forests with an enhanced management level. This type of management is preserving the remaining forests and woodlands of the country. The rate of growth of major species is slow with a tree taking around 50 years to reach 15 cm diameter at breast height (dbh) and between 70 to 100 years to reach 30 cm dbh (Mendelson and Obeid, 2004,). This implies that natural regeneration of these areas will take a long time. However, it is a good sign that all forest inventories data indicate a high number of seedlings, saplings, and young trees growing healthily. It is estimated that the clearing and felling of trees when forests were intensively exploited for timber has resulted in vast extents of the territory without a cover which had taken centuries to develop and the phenomenon of bush encroachment is the recolonization of those spaces by species better adapted to the changed climate. An extract of the report by Mendelson and Obeid is given in the NIR3 (Figure 6.3, Page 74). It is to be noted that Caprivi has been renamed Zambezi now.

***Cropland***

A steady decrease in Cropland is estimated as subsistence farming is gradually diminishing. This is due to migration of the rural population to urban areas, a higher purchasing power for a more varied food consumption pattern, improved yields from better crop husbandry practices and the combination of climate change including a higher climate variability.

***Grassland***

Bush encroachment has led to a rapid decrease in previously classified grassland (shrubland and savanna) area. These are now under the class OWL as per the presence of enough woody species.

***Wetlands***

The area of Wetlands is estimated to be constant during the whole time series. The area from the 2000 RCMRD map was used as constant.

***Settlements***

An increase in Settlement class has been included as from the NIR3. Development of infrastructure to accommodate a growing urban population plus the building of amenities have contributed to this increase. The land change was from cropland and OWL during the period 1994 to 2010. As from 2011, only OWL was converted to Settlements at a lower rate than previously seen.

***Other Land***

The class Other Land was estimated from the information in the Atlas of Namibia as the part where desert and sand were present. This area of about 11.5 M hectares lies along the coast from the north towards the south western part of Namibia. It was assumed that there was no change and no activity leading to emissions or removals in this land category.

#### 6.5.3.3. QC

A study by Barnes et al (2005) on the assessment of woody biomass stocks from forest resources arrived at 257 M $m^3$. The estimates made for the same year for the present inventory based on the area of Forestland and the woodland component of OWL is 290 M $m^3$. This is comforting and indicates that the approach adopted and the assumptions and derivations made from available information is reliable.

Cropland area were overestimated in the two previous land cover land use maps compared to real harvested area surveyed annually. It was estimated that subsistence farmers were rotating their land so that area cultivated and harvested was lower than the area under crops estimated in the maps. The movement of the population from rural to urban areas is deemed to have slowed the process of land clearing and the movement in the Cropland area is expected to be very low in this decade.

#### 6.5.3.4. Time series AD on Land Use Changes

Three time periods have been adopted as from the NIR3 for determining land use changes between the 6 IPCC classes: 1991 to 2000, 2001 to 2010 and 2011 to 2016. Initial areas for each period and annual change used in land matrices are given in Table 6.11 to Table 6.13.

**Table 6.11 - Total land use adjusted area and annual change used in land matrix (1991 - 2000)**

| Land Type category | Area (ha) | | | |
|---|---|---|---|---|
| | Year 1991 | Year 2000 | Annual gain | Annual loss |
| Forestland | 8.689,537 | 8,032,903 | - | 72,959 |
| OWL | 51,168,431 | 54,291,441 | 427,496 | 80,495 |
| Cropland | 925,000 | 625,001 | - | 37,500 |
| Grassland | 9,531,147 | 7,393,363 | 80,000 | 317,532 |
| Wetlands | 724,608 | 724,608 | - | - |
| Settlements | 20,990 | 29,896 | 990 | - |
| Other land | 11,463,570 | 11,463,570 | - | - |
| **Total** | **82,560,782** | **82,560,782** | **508,486** | **508,486** |

The major change during 1991 to 2000 is the loss of Grassland to OWL with bush encroachment. De- bushing activities to the tune of 80,000 ha annually were mitigating that effect. Forestland lost an average of 73,000 ha annually. The same annual land use changes have been applied from the year 1990 to 1991 as for the period 1991 to 2000.

**Table 6.12 - Total land use adjusted area and annual change used in land matrix (2001 - 2010)**

| Land Type category | Area (ha) | | | |
|---|---|---|---|---|
| | Year 2001 | Year 2010 | Annual gain | Annual loss |
| Forestland | 7,968,622 | 7,390,095 | 10,000 | 74,281 |
| OWL | 54,610,659 | 57,483,623 | 411,670 | 92,452 |
| Cropland | 606,698 | 441,974 | - | 18,303 |

| Land Type category | Area (ha) | | | |
|---|---|---|---|---|
| | Year 2001 | Year 2010 | Annual gain | Annual loss |
| Grassland | 7,155,832 | 5,018,049 | 82,000 | 319,531 |
| Wetlands | 724,608 | 724,608 | - | - |
| Settlements | 30,793 | 38,863 | 897 | - |
| Other land | 11,463,570 | 11,463,570 | - | - |
| **Total** | **82,560,782** | **82,560,782** | **504,567** | **504,567** |

The conversion of Grassland to OWL peaked during the period 2001 to 2010 at nearly 320,000 ha encroached every year. A conversion of OWL to Forestland at the rate of 10,000 ha per year is now included as bush encroached land meets the Forestland definition.

**Table 6.13 - Total land use adjusted area and annual change used in land matrix (2011 - 2016)**

| Land Type category | Area (ha) | | | |
|---|---|---|---|---|
| | Year 2011 | Year 2016 | Annual gain | Annual loss |
| Forestland | 7,328,707 | 7,021,766 | 10,000 | 71,388 |
| OWL | 57,672,871 | 58,619,108 | 289,361 | 100,114 |
| Cropland | 432,777 | 386, 790 | - | 9,197 |
| Grassland | 4,899,273 | 4,305,395 | 90,000 | 208,776 |
| Wetlands | 724,608 | 724,608 | - | - |
| Settlements | 38,977 | 39,545 | 114 | - |
| Other land | 11,463,570 | 11,463,570 | - | - |
| **Total** | **82,560,782** | **82,560,782** | **389,475** | **389,475** |

During 2011 to 2016, the rate of loss of Cropland and Grassland decreased. The rate of increase of Settlements also slowed down.

It is a fact that this approach which has been adopted in the BUR3, NC4 and BUR4 may not be representative of the national situation, but it is considered better than the one adopted in the previous inventories. The intent of the country is to develop a new set of land cover land use maps over a few time steps of the inventory period to overcome the inaccuracies in the representation of land.

#### 6.5.3.5. Soil type

Another hurdle is the sub-division of land into 4 different soil types. The High Activity Clay (HAC) and Low Activity Clay (LAC) soil types were the most abundant and kept from the NIR2. While segregation brings accuracy in the estimates, this is not easy to accommodate in the IPCC Inventory Software at the Tier 2 level being implemented. Thus, a weighted average of the soil factors, using the areas determined by RCMRD, was calculated and used for the whole of Namibia. A summary of the various soil types and the weightage used for deriving user-defined factors is given in Table 6.14.

**Table 6.14 - % Distribution of different soil types in Namibia**

| Parameter | Soil type | | | |
|---|---|---|---|---|
| | HAC | LAC | SAN (Sandy Mineral) | WET (Wetland) |
| Area (ha) | 50,128,385 | 90,367 | 32,340,961 | 1,069 |
| % of total area | 60.7% | 0.1% | 39.2% | 0.0% |

#### 6.5.3.6. Climate

In the NIRs 1 and 2, two climate types were allocated by RCMRD in association with the different soil types. During the review and development of the new approach as from the NIR3 up to now, the climate assigned to Namibia which was wrong has been corrected. After confirmation from IPCC map (2006 IPCC GL, Volume 4, page 3.38, Figure 3.A.5.1), the climate of Namibia is now set as Temperate dry for the whole country since the small area associated with the Tropical dry climate type is situated in the Other Land class where there is no activity.

A Tier 2 approach has been maintained but slight changes brought as follows:

(i) This is highly supported from the results of the censuses indicating a much lower use of local wood resources.

(ii) The lower reliance on local wood resources is attributed to a rise in urbanization rate accompanied by a fall in woody material used for dwellings coupled with use of alternative materials for dwellings, imports of wood from neighbouring South Africa, lower use of wood as fuel for cooking, heating and lighting, and reduced commercial harvest of wood.

(iii) Thus, compared to FRA data, slower biomass accumulation rates have been adopted over the 20 years of this time series (see matrices provided separately).

(iv) Bush encroachment has resulted in vast areas of land previously misclassed as shrubland/savanna/grassland to be reclassified as forest or dense woodlands now.

(v) Bush encroachment rate and bush clearing have been taken into consideration in the land use changes.

(vi) Additionally, by combining shrubland, savanna and open woodland under the common class Other Wooded Land to enable computation of emissions and removals in the software, compilation has been simplified.

(vii) It is essential to account for the biomass of the bushes properly, including their role in wood removals. Emission and stock factors (growing stock, annual growth rates, etc.) have been derived for the country based on the latest information available

(viii) Most wood removals are accounted for in this new OWL as is presently the case for known uses of woody biomass stocks.

(ix) An increase in Settlement land category is included in the change as population and urbanization is constantly increasing. This is estimated to be accompanied by a loss in Cropland area whereby subsistence farming is regressing, and villages are also extending.

### 6.5.4. Generated data and emission factors

#### 6.5.4.1. Biomass stock factors

The standing biomass stock for Forestland was obtained by averaging the data from Forest inventory reports performed in preserved forests, community forests and conservancies in areas receiving adequate rainfall to maintain trees. Regarding Other Wooded Land, the standing biomass stocks of land defined as woodlands, shrubland and savannahs in forest inventories were pooled to provide a weighted average on area basis for OWL. The areas used pertained to the 1990 areas allocated to these different land cover classes. The information from the different national forest inventory (NFI) reports and the land cover classes considered for deriving the user-defined stock factor for Forestland and OWL have been provided in the NIR3 (Table 6.15, Page 78). The data obtained from the NFIs were further aggregated on a weight basis to generate CS biomass stocks. Table 6.15 shows the different biomass factors derived for the Forestland, OWL and Grassland categories.

**Table 6.15 - Biomass stock factors for FOLU.**

| Land classes | Woody biomass (t/ha) | Deadwood (m3) | Above ground Biomass (t dm/ha) | Age to reach this class (yrs) | Annual growth (t dm/yr) | Grass layer (t dm/ha) |
|---|---|---|---|---|---|---|
| Forestland | 22.63 | 2.76 | 38.47 | 100.0 | 0.385 | 0.23 |
| OWL | 12.13 | 1.48 | 36.38 | 45.6 | 0.797 | 0.69 |
| Grassland | | | | | | 1.15 |

### 6.5.4.2. Wood removals

Removal of fuelwood was indexed on its rate use by urban and rural population respectively. Removal of timber and poles were based on number of traditional dwellings and the amount of woody resources needed to build and maintain these units.

Charcoal produced was estimated from trade statistics, converted to woody biomass and included in the fuelwood estimates.

The amount of woody biomass removed is provided in Table 6.16.

**Table 6.16 - Wood removals (t) from various activities (1990 - 2016)**

| Year | Charcoal production | Fuelwood exported | Fuelwood collected | Poles removal | Bushblock production | Industrial consumption | Total |
|---|---|---|---|---|---|---|---|
| 1990 | 300,000 | 500 | 301,400 | 154,728 | | | 756,628 |
| 1991 | 300,000 | 500 | 307,432 | 164,737 | * | * | 772,669 |
| 1992 | 300,000 | 500 | 309,430 | 162,224 | * | * | 772,154 |
| 1993 | 300,000 | 500 | 311,426 | 165,727 | * | * | 777,653 |
| 1994 | 300,000 | 500 | 313,419 | 169,068 | * | * | 782,987 |
| 1995 | 300,000 | 500 | 315,409 | 172,245 | * | * | 788,154 |
| 1996 | 300,000 | 500 | 317,396 | 175,259 | * | * | 793,155 |
| 1997 | 300,000 | 500 | 319,380 | 178,111 | * | * | 797,991 |
| 1998 | 300,000 | 555 | 321,363 | 180,799 | * | * | 802,716 |
| 1999 | 300,000 | 621 | 323,342 | 183,323 | * | * | 807,287 |
| 2000 | 300,000 | 152 | 325,320 | 185,685 | * | * | 811,157 |
| 2001 | 300,000 | 122 | 327,295 | 187,946 | 8,000 | * | 823,363 |
| 2002 | 300,000 | 130 | 330,722 | 190,055 | 8,000 | * | 828,907 |
| 2003 | 300,000 | 68 | 334,160 | 193,325 | 8,000 | * | 835,553 |
| 2004 | 301,044 | 2,469 | 337,610 | 200,640 | 8,000 | * | 849,763 |
| 2005 | 294,031 | 4,486 | 341,070 | 194,950 | 8,000 | * | 842,537 |

| Year | Charcoal production | Fuelwood exported | Fuelwood collected | Poles removal | Bushblock production | Industrial consumption | Total |
|---|---|---|---|---|---|---|---|
| 2006 | 320,779 | 7,120 | 344,540 | 201,706 | 8,000 | * | 882,144 |
| 2007 | 374,117 | 7,553 | 348,019 | 197,702 | 8,000 | * | 935,390 |
| 2008 | 523,727 | 11,651 | 351,507 | 198,838 | 8,000 | * | 1,093,723 |
| 2009 | 693,161 | 14,251 | 355,002 | 199,816 | 8,000 | * | 1,270,230 |
| 2010 | 621,187 | 14,467 | 358,504 | 200,112 | 8,000 | * | 1,202,270 |
| 2011 | 465,524 | 14,571 | 363,330 | 204,371 | 8,000 | * | 1,055,797 |
| 2012 | 471,321 | 15,116 | 359,217 | 201,247 | 8,000 | 27,000 | 1,081,901 |
| 2013 | 549,841 | 14,997 | 354,888 | 201,552 | 8,000 | 30,000 | 1,159,279 |
| 2014 | 541,410 | 15,909 | 350,337 | 201,631 | 8,000 | 27,000 | 1,144,287 |
| 2015 | 645,763 | 19,277 | 345,558 | 201,547 | 8,000 | 27,000 | 1,247,144 |
| 2016 | 683,445 | 19,470 | 340,544 | 201,300 | 8,000 | 9,356 | 1,262,115 |

*** Not Occurring**

Woody biomass removals were allocated as follows:

(i) Charcoal from OWL as de-bushing activities are the major contributor to charcoal production
(ii) All fuelwood from OWL.
(iii) Poles removal were accounted for as 50% from forestland and 50% OWL during the period 1990 to 2000, 40% from forestland and 60% from OWL during the period 2001 to 2010 and 30% and 70% as from 2011 to 2016. This mix is based on 1% population migrating from rural to urban areas and relieving the use for dwellings and the shift to other building materials as well as imports of wood for construction purposes.

#### 6.5.4.3. Area disturbed

Information from MAWF was available for the years 2000 to 2016 for total area burnt. Trending technique was used to generate the areas burnt from 1990 to 1999. This area was apportioned according to area under Forestland, OWL and Grassland classes on a weight basis. It was estimated that 1% of the biomass stock was lost during disturbance occurring in Forestland, 5% in OWL and 30% of the grass layer of Grasslands. The annual area burnt and its breakdown is given in Table 6.17.

**Table 6.17 - Distribution of annual area disturbed by fire (1990 - 2016)**

| Year | Total | Area (ha) disturbed by fire | | |
|---|---|---|---|---|
| | | Forestland | OWL | Grassland |
| 1990 | 9,359,820 | 1,188,958 | 6,942,697 | 1,228,165 |
| 1991 | 8,918,116 | 1,118,855 | 6,633,724 | 1,165,537 |
| 1992 | 8,476,412 | 1,050,244 | 6,322,761 | 1,103,406 |
| 1993 | 8,034,708 | 986,492 | 6,030,524 | 1,017,692 |
| 1994 | 7,593,004 | 923,742 | 5,734,154 | 935,108 |
| 1995 | 7,151,300 | 861,991 | 5,433,660 | 855,649 |
| 1996 | 6,709,596 | 801,238 | 5,129,046 | 779,311 |
| 1997 | 6,267,892 | 741,482 | 4,820,321 | 706,089 |
| 1998 | 5,826,188 | 682,720 | 4,507,490 | 635,978 |
| 1999 | 5,384,484 | 624,952 | 4,190,560 | 568,972 |
| 2000 | 4,851,640 | 557,698 | 3,798,187 | 495,755 |
| 2001 | 4,868,950 | 555,058 | 3,833,225 | 480,667 |

| Year | Total | Area (ha) disturbed by fire | | |
|---|---|---|---|---|
| | | Forestland | OWL | Grassland |
| 2002 | 3,667,000 | 414,528 | 2,903,128 | 349,343 |
| 2003 | 3,663,350 | 410,613 | 2,916,389 | 336,348 |
| 2004 | 3,245,920 | 360,722 | 2,598,376 | 286,822 |
| 2005 | 4,044,970 | 445,658 | 3,255,834 | 343,478 |
| 2006 | 5,205,020 | 568,498 | 4,212,481 | 424,042 |
| 2007 | 6,136,760 | 664,407 | 4,993,548 | 478,805 |
| 2008 | 3,775,280 | 405,137 | 3,088,588 | 281,556 |
| 2009 | 7,291,860 | 775,560 | 5,997,580 | 518,720 |
| 2010 | 6,197,680 | 653,278 | 5,124,840 | 419,562 |
| 2011 | 6,642,550 | 693,422 | 5,500,960 | 448,168 |
| 2012 | 6,922,060 | 716,395 | 5,750,525 | 455,140 |
| 2013 | 1,924,180 | 197,417 | 1,603,547 | 123,216 |
| 2014 | 2,829,330 | 287,749 | 2,365,260 | 176,322 |
| 2015 | 2,319,940 | 233,864 | 1,945,479 | 140,597 |
| 2016 | 1,147,370 | 114,634 | 965,169 | 67,567 |

#### 6.5.4.4. Emissions and Removals estimates

Estimates of emissions and removals for the Land sector are given in Table 6.18. Namibia remained a sink during the whole time series. Removals resulting from biomass accumulation outpaced emissions. Bush encroachment and its thickening is responsible for the removals and the maintenance of the sink capacity. The removals in Forestland increased from -90,021 Gg $CO_2$ in 1990 to -122,817 Gg $CO_2$ in 2013 to regress slightly over the next 2 years and increased again to - 126,598 Gg $CO_2$ in 2016. Emissions from grassland increased from 8,672 Gg $CO_2$ to reach 9,756 Gg in 2016. Emissions from land converted to settlements decreased from 63 Gg $CO_2$ to 13 Gg $CO_2$ in line with converted area. Net removals varied from a minimum of -81,286 Gg $CO_2$ in 1990 and -116,829 Gg $CO_2$ in 2016.

**Table 6.18 - Emissions ($CO_2$) for the Land sector (1990 - 2016)**

| Year | 3.B.1 - Forest land | 3.B.3 - Grassland | 3.B.5 - Settlements | Net Removals |
|---|---|---|---|---|
| 1990 | -90,021 | 8,672 | 63 | -81,286 |
| 1991 | -91,794 | 8,672 | 63 | -83,059 |
| 1992 | -93,706 | 8,672 | 63 | -84,971 |
| 1993 | -95,488 | 8,672 | 63 | -86,753 |
| 1994 | -97,288 | 8,672 | 63 | -88,553 |
| 1995 | -99,105 | 8,672 | 63 | -90,370 |
| 1996 | -100,940 | 8,672 | 63 | -92,205 |
| 1997 | -102,793 | 8,672 | 63 | -94,057 |
| 1998 | -104,662 | 8,672 | 63 | -95,927 |
| 1999 | -106,549 | 8,672 | 63 | -97,814 |
| 2000 | -108,758 | 8,672 | 63 | -100,023 |
| 2001 | -108,915 | 8,889 | 58 | -99,969 |
| 2002 | -113,365 | 8,889 | 58 | -104,418 |
| 2003 | -113,782 | 8,889 | 58 | -104,835 |

| Year | 3.B.1 - Forest land | 3.B.3 - Grassland | 3.B.5 - Settlements | Net Removals |
|---|---|---|---|---|
| 2004 | -115,577 | 8,889 | 58 | -106,631 |
| 2005 | -113,322 | 8,889 | 58 | -104,375 |
| 2006 | -109,695 | 8,889 | 58 | -100,749 |
| 2007 | -106,905 | 8,889 | 58 | -97,959 |
| 2008 | -115,501 | 8,889 | 58 | -106,554 |
| 2009 | -103,624 | 8,889 | 58 | -94,677 |
| 2010 | -107,834 | 8,889 | 58 | -98,888 |
| 2011 | -105,880 | 9,756 | 13 | -96,111 |
| 2012 | -104,930 | 9,756 | 13 | -95,162 |
| 2013 | -122,817 | 9,756 | 13 | -113,048 |
| 2014 | -119,907 | 9,756 | 13 | -110,138 |
| 2015 | -121,992 | 9,756 | 13 | -112,223 |
| 2016 | -126,598 | 9,756 | 13 | -116,829 |

## 6.6. Aggregated sources and non-$CO_2$ emission sources on Land

### 6.6.1. Description of category

Aggregated sources and non-$CO_2$ emission sources on Land in Namibia originated from four of the IPCC categories and all four with activities occurring were covered in this inventory. The categories are

- 3.C.1 Biomass burning;
- 3.C.4 Direct emissions from managed soils;
- 3.C.5 Indirect emissions from managed soils; and
- 3.C.6 Indirect emissions from manure management.

### 6.6.2. Methods

Methods are according to the IPCC 2006 Guidelines and the 2006 IPCC Software has been used to compute emissions for these categories.

### 6.6.3. Activity data

The AD are those adopted for computing direct emissions for the land and livestock categories, which are used by default in the software to aggregate emissions from different sources. Here, reference is made to the manure generated by livestock and area disturbed with their biomass stocks.

AD for fertilizers and urea are from the mass balance of imports and exports data from the NSA. The statistics did not refer to the exact N content as required for input in the software but rather by fertilizer type. A description of the fertilizers imported and used in the country along with their N content is provided in the NIR3 (Table 6.20, Page 82). While the N content of certain straight fertilizers are known, the molecular formula was used in some cases to estimate the N contents of blends/mixtures. No import and export data were available for the period 1990 to 1997 and the average N used in the years 1998 to 2000 was adopted as AD for these years.

The total amount of N obtained from the fertilizers used and keyed in the software for estimating emissions is provided in Table 6.19. The very high use of synthetic N fertilizer for the period 2011 to 2016 was due to a donation from a friendly country.

**Table 6.19 - Amount of N (kg) used from fertilizer application (1990 - 2016)**

| Type of fertilizer | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Urea N | 212,650 | 212,650 | 212,650 | 212,650 | 212,650 | 212,650 | 212,650 | 168,158 | 142,158 | 327,634 | 1,888,517 | 1,291,430 | 542,740 | 368,488 |
| Synthetic fertilizer N | 711,152 | 711,152 | 711,152 | 711,152 | 711,152 | 711,152 | 711,152 | 711,152 | 761,278 | 579,424 | 792,753 | 789,181 | 1,405,803 | 1,044,076 |

| Type of fertilizer | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Urea N | 212,650 | 126,153 | 90,414 | 173,177 | 32,491 | 103,965 | 50,217 | 269,867 | 319,444 | 212,319 | 176,470 | 294,984 | 787,922 |
| Synthetic fertilizer N | 4,081,591 | 4,511,194 | 5,795,314 | 6,791,457 | 4,703,351 | 7,482,384 | 10,949,854 | 12,111,961 | 12,532,870 | 9,688,535 | 5,013,240 | 11,823,803 | 20,709,244 |

## 6.6.4. Emission factors

Biomass burning is known to occur in the country on account of wildfires. Default EFs were used for all gases in Forestland, OWL and Grassland burning. Biomass burning is a key category in some years on account of the vast areas burned rather than the EFs. Thus, it is not contemplated to attempt at deriving national ones. However, the amount of standing biomass in the different land classes will be further refined when new forest inventories will be performed. Default EFs were used for estimating emissions from urea application as well as for estimates of indirect emissions from managed soils and manure management.

## 6.6.5. Emission estimates

The emissions for aggregate sources and non-$CO_2$ emissions on land are given in Table 6.20. Emissions varied between 2,881 Gg $CO_2$-eq and 6,702 Gg $CO_2$-eq for the period 1990 to 2016. This high variability in estimates is attributed to the varying areas disturbed by wildfires between years and this is very difficult to control.

**Table 6.20 - Aggregated emissions (Gg $CO_2$-eq) for aggregate sources and non-$CO_2$ emissions on Land (1990 - 2016)**

| 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6,702 | 6,538 | 6,249 | 5,925 | 5,685 | 5,502 | 5,196 | 5,026 | 4,828 | 4,636 | 4,442 | 4,510 | 3,789 | 3,837 |

| 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3,583 | 3,968 | 4,717 | 5,179 | 3,921 | 5,997 | 5,265 | 5,840 | 6,145 | 2,957 | 3,622 | 3,312 | 2,881 |

The emissions for the direct and indirect GHGs are given in Table 6.21. The major gas emitted among the direct ones in this category remained $CH_4$ throughout the period followed by $N_2O$. $CO_2$ emissions were minimal for all years. For the indirect gases, CO emissions was substantial, varying between 349 to 2,627 Gg. This general reduction trend is attributed to lower areas burned in wildfires resulting from improved management of Forestland and Grassland.

Table 6.21 - Emissions (Gg) by gas for aggregate sources and non-$CO_2$ emissions on Land (1990 - 2016)

| Year | $CO_2$ | $CH_4$ | $N_2O$ | NOx | CO |
|---|---|---|---|---|---|
| 1990 | 0.34 | 171.1 | 10.0 | 41.4 | 2,627 |
| 1991 | 0.34 | 163.2 | 10.0 | 39.5 | 2,505 |
| 1992 | 0.34 | 155.3 | 9.6 | 37.5 | 2,383 |
| 1993 | 0.34 | 147.8 | 9.1 | 35.7 | 2,268 |
| 1994 | 0.34 | 140.2 | 8.8 | 33.8 | 2,152 |
| 1995 | 0.34 | 132.6 | 8.8 | 32.0 | 2,035 |
| 1996 | 0.34 | 124.9 | 8.3 | 30.1 | 1,917 |
| 1997 | 0.34 | 117.2 | 8.3 | 28.2 | 1,798 |
| 1998 | 0.27 | 109.4 | 8.2 | 26.3 | 1,678 |
| 1999 | 0.23 | 101.5 | 8.1 | 24.4 | 1,557 |
| 2000 | 0.52 | 91.8 | 8.2 | 22.1 | 1,408 |
| 2001 | 3.01 | 92.5 | 8.3 | 22.2 | 1,419 |
| 2002 | 2.06 | 70.0 | 7.5 | 16.8 | 1,073 |
| 2003 | 0.87 | 70.2 | 7.6 | 16.8 | 1,076 |
| 2004 | 0.59 | 62.4 | 7.3 | 14.9 | 957 |
| 2005 | 0.20 | 78.1 | 7.5 | 18.7 | 1,197 |
| 2006 | 0.14 | 100.8 | 8.4 | 24.1 | 1,546 |
| 2007 | 0.28 | 115.6 | 8.9 | 28.5 | 1,829 |
| 2008 | 0.05 | 73.7 | 7.7 | 17.6 | 1,130 |
| 2009 | 0.17 | 142.9 | 9.7 | 34.1 | 2,190 |
| 2010 | 0.08 | 121.9 | 8.7 | 29.1 | 1,868 |
| 2011 | 0.43 | 130.7 | 10.0 | 31.2 | 2,003 |
| 2012 | 0.51 | 136.5 | 10.6 | 32.5 | 2,091 |
| 2013 | 0.34 | 38.0 | 7.0 | 9.1 | 582 |
| 2014 | 0.28 | 56.0 | 7.9 | 13.3 | 858 |
| 2015 | 0.47 | 46.0 | 7.6 | 11.0 | 705 |
| 2016 | 1.26 | 22.8 | 7.7 | 5.4 | 349 |

## 6.7. Harvested Wood Products (HWP)

### 6.7.1. Description of the HWP category

Emissions from cut trees do not necessarily occur in the same year but depend on the fate of the harvested wood, unless it is burned in the same year. Thus, the category HWP to account for the sink created by the harvested wood used as a commodity for housing, furniture and other uses. This category was not previously covered in previous inventories of Namibia primarily because of lack of available data and other information required to allow for emissions to be estimated with a certain level of certainty. Now that the background work has been completed, the category HWP is not covered as one of the listed improvement areas. The period 1998 to 2016 only is covered presently until AD is sourced for the remaining years 1990 to 1997 of the time series.

### 6.7.2. Method

The Tier 1 method recommended in the IPCC 2006 Guidelines was adopted for estimating emissions or removals from this category. The stock change approach was used, based on the AD that were available.

### 6.7.3. Activity data

Available trade statistics on wood and other wood products for the period 1998 to 2016 were preferred to the datasets available on the FAO database as most of the latter were estimates. Wood and its products were regrouped to align them with the different groups used in the computation of emissions as per the 2006 software requirements. The trade data were supplemented with those available in the FAO database, which covers the period 2000 to 2016 only, to fill any existing gap and also as a method of QC of the national data available. Additionally, AD on wood removals from forests used in the Land category was used as production data to complement the trade and FAO statistics which covered the import and export part.

Based on information collected from the authorities dealing with waste and the environment, it was assumed that there were no production of wood pulp and recycling of paper in the country. Outliers in the timeseries AD were corrected using statistical techniques, namely trending or averaging based on analysis of the available data.

Trade statistics were obtained from NSA for the period 1998 to 2016. Different groups of Harmonised System (HS) codes were analysed and combined under each header required for the HWP software data entry. The information which was in weight was then converted to the units required by the software. Data for fuelwood were generated since the year 1961 based on use rate and population.

The AD was then compared to information from FAO which existed for the years 2000 to 2016. The FAO statistics were analysed, and the information regrouped under each header required for the HWP software data entry. There were differences probably resulting from the classification of the HS codes in the various elements and the estimates made in the FAO statistics and it was decided to keep the national statistics as AD. It is assumed that there are no production of wood pulp/recycled paper in Namibia.

Outliers were corrected using statistical techniques such as trending and averaging.

### 6.7.4. Timeseries Activity data

AD from HWP category are presented in Table 6.22. All components required by the software were allocated.

## Table 6.22 - Activity data for HWP from trade statistics (1998 - 2016)

| | Roundwood (m3) | | | Sawnwood (m3)* | | Wood-based panels (m3)* | | Paper + Paperboard (t)* | | Wood Pulp (1875)+ recycled paper (t)* | | Industrial roundwood (m3)* | | Chips and particles (m3) | | Wood charcoal (t) | | | Wood residues (m3) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Production | Import | Export | Import | Export | Import | Export | Import | Export | Import | Export | Import | Export | Import | Export | Production | Import | Export | Import | Export |
| 1998 | 504,448 | 355 | 1,148 | 32,031 | 4,257 | 10,454 | 73 | 92,743 | 5,886 | 181 | 3,578 | 21,038 | 1,283 | 136 | 298 | 60,000 | 670 | 9,572 | 359 | 78 |
| 1999 | 510,383 | 405 | 1,292 | 30,077 | 1,957 | 13,445 | 129 | 128,648 | 6,266 | 118 | 3,357 | 17,406 | 469 | 414 | 1,301 | 60,000 | 733 | 177,684 | 176 | 1 |
| 2000 | 515,522 | 483 | 700 | 29,458 | 3,391 | 13,145 | 79 | 54,987 | 7,096 | 65 | 2,933 | 15,628 | 618 | 165 | 757 | 60,000 | 1,961 | 9,782 | 102 | 7 |
| 2001 | 520,941 | 400 | 574 | 36,559 | 2,534 | 14,282 | 161 | 131,958 | 5,492 | 156 | 4,537 | 21,396 | 1,554 | 167 | 1,570 | 60,000 | 2,330 | 26,039 | 280 | 509 |
| 2002 | 524,637 | 159 | 345 | 20,753 | 4,418 | 5,854 | 662 | 27,304 | 2,666 | 103 | 4,582 | 22,249 | 1,599 | 244 | 863 | 60,000 | 131 | 20,683 | 109 | 0 |
| 2003 | 530,183 | 482 | 580 | 41,336 | 10,089 | 10,820 | 606 | 50,273 | 3,957 | 149 | 7,703 | 19,789 | 2,658 | 429 | 295 | 60,000 | 520 | 35,425 | 36 | 79 |
| 2004 | 544,919 | 418 | 3,944 | 31,344 | 11,437 | 12,303 | 3,000 | 47,864 | 4,568 | 72 | 8,709 | 24,122 | 3,781 | 97 | 19 | 60,209 | 756 | 50,965 | 284 | 96 |
| 2005 | 537,582 | 925 | 7,334 | 42,628 | 9,039 | 13,400 | 4,818 | 46,430 | 4,910 | 27 | 8,076 | 32,198 | 4,144 | 64 | 137 | 58,806 | 711 | 49,517 | 31 | 60 |
| 2006 | 551,592 | 108 | 10,280 | 35,278 | 7,878 | 18,185 | 1,277 | 49,735 | 3,456 | 24 | 7,463 | 30,272 | 5,789 | 88 | 714 | 64,156 | 137 | 54,293 | 21 | 3 |
| 2007 | 545,453 | 192 | 10,982 | 37,474 | 8,854 | 18,408 | 164 | 54,905 | 2,477 | 117 | 8,982 | 31,129 | 11,155 | 614 | 1,131 | 74,823 | 13 | 64,837 | 14 | 0 |
| 2008 | 551,533 | 130 | 16,775 | 37,280 | 12,394 | 20,811 | 824 | 57,008 | 4,587 | 339 | 9,708 | 29,075 | 10,804 | 579 | 512 | 104,745 | 19 | 94,764 | 27 | 1 |
| 2009 | 555,834 | 203 | 20,561 | 83,510 | 14,596 | 22,998 | 935 | 67,604 | 6,193 | 107 | 11,729 | 41,529 | 10,305 | 7 | 425 | 138,632 | 21 | 128,654 | 38 | 0 |
| 2010 | 556,602 | 64 | 20,731 | 45,610 | 8,517 | 20,033 | 266 | 67,345 | 3,383 | 950 | 11,913 | 42,203 | 5,734 | 66 | 253 | 124,237 | 48 | 114,286 | 90 | 25 |
| 2011 | 563,848 | 89 | 20,906 | 45,038 | 6,488 | 61,361 | 345 | 64,449 | 3,525 | 322 | 13,138 | 43,812 | 3,909 | 114 | 64 | 93,105 | 68 | 83,172 | 39 | 44 |
| 2012 | 557,982 | 95 | 21,690 | 53,831 | 7,481 | 21,233 | 404 | 72,753 | 10,492 | 95 | 14,120 | 49,912 | 6,184 | 378 | 242 | 94,264 | 646 | 84,910 | 597 | 160 |
| 2013 | 557,233 | 414 | 21,838 | 52,549 | 8,265 | 25,288 | 185 | 74,338 | 14,468 | 284 | 13,596 | 60,693 | 6,024 | 1,130 | 38 | 109,968 | 524 | 100,492 | 621 | 113 |
| 2014 | 557,201 | 477 | 23,204 | 60,639 | 9,608 | 20,914 | 254 | 83,944 | 16,986 | 65 | 14,578 | 61,312 | 8,017 | 1,085 | 99 | 108,282 | 11,244 | 109,527 | 234 | 128 |
| 2015 | 559,418 | 444 | 27,982 | 57,906 | 12,868 | 27,006 | 261 | 88,851 | 24,695 | 69 | 16,023 | 75,092 | 5,031 | 914 | 207 | 129,153 | 144 | 119,297 | 1,451 | 99 |
| 2016 | 935,523 | 729 | 28,553 | 52,799 | 7,287 | 28,773 | 222 | 78,541 | 11,496 | 79 | 14,328 | 69,465 | 5,901 | 38 | 804 | 54 | 117,652 | 1,996 | 68 | 2016 |

* Production columns are not shown for items where the data is zero

## Emission factors

Default EF from the IPCC 2006 Guidelines (V4_12_Ch12-HWP Table 12.2 Page 12.17) were used for estimating emissions and removals. These are given in Table 6.23.

**Table 6.23 - Emission factors used for HWP**

| Parameters | Item | Value | Units |
|---|---|---|---|
| Half Life | Solid wood products | 30 | years |
| | Paper product | 2 | years |
| Conversion factors | Sawnwood, other | 0.5 | t C/m3 |
| | Wood based panels | 0.295 | t C/m3 |
| | Paper products | 0.450 | t C/adt |
| | Wood charcoal | 0.765 | t C/adt |
| | Bark | 1.120 | $C_{overb} / C_{underb}$ |
| Growth rate | | 0.0287 | 1/year |

## Results

Only one gas, $CO_2$ is emitted or removed in the HWP category. Emissions and removals from the HWP category are given in Table 6.24. The HWP category constituted a sink throughout the period 1998 to 2015 except for the year 2002 when it emitted 39.4 Gg of $CO_2$. The removals varied between 21.0 and 199.0 Gg, which occurred in 1999.

**Table 6.24 - Emissions (Gg) from Harvested Wood Products (1998 - 2016)**

| Year | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|---|---|
| Emission/Removals | -182.6 | -199.0 | -50.1 | -176.3 | 39.4 | -42.7 | -21.0 | -46.7 | -53.9 | -65.8 |

| Year | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|
| Emission/Removals | -57.8 | -149.9 | -85.7 | -122.4 | -91.0 | -84.7 | -99.9 | -86.5 | -90.4 |

**Table 6.25 - Sectoral Table AFOLU sector (Inventory Year: 2016)**

| Categories | Net $CO_2$ emissions / removals | Emissions (Gg) | | | | |
|---|---|---|---|---|---|---|
| | | $CH_4$ | $N_2O$ | NOx | CO | NMVOCs |
| 3 - Agriculture, Forestry, and Other Land Use | -116918.432 | 217.723 | 8.257 | 5.426 | 349.270 | 13.544 |
| 3.A - Livestock | NA | 194.921 | 0.511 | NA | NA | 13.544 |
| 3.A.1 - Enteric Fermentation | NA | 190.456 | NA | NA | NA | NA |
| 3.A.1.a - Cattle | NA | 169.617 | NA | NA | NA | NA |
| 3.A.1.a.i - Dairy Cows | NA | 0.183 | NA | NA | NA | NA |
| 3.A.1.a.ii - Other Cattle | NA | 169.434 | NA | NA | NA | NA |
| 3.A.1.b - Buffalo | NA | NO | NA | NA | NA | NA |
| 3.A.1.c - Sheep | NA | 8.733 | NA | NA | NA | NA |
| 3.A.1.d - Goats | NA | 9.843 | NA | NA | NA | NA |
| 3.A.1.e - Camels | NA | 0.001 | NA | NA | NA | NA |
| 3.A.1.f - Horses | NA | 0.733 | NA | NA | NA | NA |

| Categories | Net $CO_2$ emissions / removals | Emissions (Gg) | | | | |
|---|---|---|---|---|---|---|
| | | $CH_4$ | $N_2O$ | NOx | CO | NMVOCs |
| 3.A.1.g - Mules and Asses | NA | 1.446 | NA | NA | NA | NA |
| 3.A.1.h - Swine | NA | 0.083 | NA | NA | NA | NA |
| 3.A.1.j - Other (please specify) | NA | 0.000 | NA | NA | NA | NA |
| 3.A.2 - Manure Management (1) | NA | 4.466 | 0.511 | NA | NA | 13.544 |
| 3.A.2.a - Cattle | NA | 3.254 | 0.504 | NA | NA | 11.448 |
| 3.A.2.a.i - Dairy cows | NA | 0.002 | 0.002 | NA | NA | 0.016 |
| 3.A.2.a.ii - Other cattle | NA | 3.252 | 0.502 | NA | NA | 11.432 |
| 3.A.2.b - Buffalo | NA | NO | NA | NA | NA | 0.000 |
| 3.A.2.c - Sheep | NA | 0.349 | NA | NA | NA | 0.295 |
| 3.A.2.d - Goats | NA | 0.433 | NA | NA | NA | 1.067 |
| 3.A.2.e - Camels | NA | 0.000 | NA | NA | NA | 0.000 |
| 3.A.2.f - Horses | NA | 0.089 | NA | NA | NA | 0.174 |
| 3.A.2.g - Mules and Asses | NA | 0.174 | NA | NA | NA | 0.213 |
| 3.A.2.h - Swine | NA | 0.083 | 0.004 | NA | NA | 0.046 |
| 3.A.2.i - Poultry | NA | 0.084 | 0.002 | NA | NA | 0.301 |
| 3.A.2.j - Other (please specify) | NA | NA | NA | NA | NA | NA |
| 3.B - Land | -116829.341 | NA | NO | NO | NO | NO |
| 3.B.1 - Forest land | -126598.050 | NA | NO | NO | NO | NO |
| 3.B.1.a - Forest land Remaining Forest land | -125635.339 | NA | NA | NO | NO | NO |
| 3.B.1.b - Land Converted to Forest land | -962.711 | NA | NA | NO | NO | NO |
| 3.B.1.b.i - Cropland converted to Forest Land | -62.193 | NA | NA | NO | NO | NO |
| 3.B.1.b.ii - Grassland converted to Forest Land | -900.518 | NA | NA | NO | NO | NO |
| 3.B.1.b.iii - Wetlands converted to Forest Land | NO | NA | NA | NO | NO | NO |
| 3.B.1.b.iv - Settlements converted to Forest Land | NO | NA | NA | NO | NO | NO |
| 3.B.1.b.v - Other Land converted to Forest Land | NO | NA | NA | NO | NO | NO |
| 3.B.2 - Cropland | NO | NA | NA | NO | NO | NO |
| 3.B.2.a - Cropland Remaining Cropland | NO | NA | NA | NO | NO | NO |
| 3.B.2.b - Land Converted to Cropland | NO | NA | NA | NO | NO | NO |
| 3.B.2.b.i - Forest Land converted to Cropland | NO | NA | NA | NO | NO | NO |
| 3.B.2.b.ii - Grassland converted to Cropland | NO | NA | NA | NO | NO | NO |
| 3.B.2.b.iii - Wetlands converted to Cropland | NO | NA | NA | NO | NO | NO |
| 3.B.2.b.iv - Settlements converted to Cropland | NO | NA | NA | NO | NO | NO |
| 3.B.2.b.v - Other Land converted to Cropland | NO | NA | NA | NO | NO | NO |
| 3.B.3 - Grassland | 9755.939 | NA | NA | NO | NO | NO |
| 3.B.3.a - Grassland Remaining Grassland | NO | NA | NA | NO | NO | NO |
| 3.B.3.b - Land Converted to Grassland | 9755.939 | NA | NA | NO | NO | NO |
| 3.B.3.b.i - Forest Land converted to Grassland | 9755.939 | NA | NA | NO | NO | NO |

| Categories | Net $CO_2$ emissions / removals | Emissions (Gg) | | | | |
|---|---|---|---|---|---|---|
| | | $CH_4$ | $N_2O$ | NOx | CO | NMVOCs |
| 3.B.3.b.ii - Cropland converted to Grassland | NO | NA | NA | NO | NO | NO |
| 3.B.3.b.iii - Wetlands converted to Grassland | NO | NA | NA | NO | NO | NO |
| 3.B.3.b.iv - Settlements converted to Grassland | NO | NA | NA | NO | NO | NO |
| 3.B.3.b.v - Other Land converted to Grassland | NO | NA | NA | NO | NO | NO |
| 3.B.4 - Wetlands | NO | NO | NO | NO | NO | NO |
| 3.B.4.a - Wetlands Remaining Wetlands | NO | NO | NO | NO | NO | NO |
| 3.B.4.a.i - Peatlands remaining peatlands | NO | NO | NO | NO | NO | NO |
| 3.B.4.a.ii - Flooded land remaining flooded land | NA | NO | NO | NO | NO | NO |
| 3.B.4.b - Land Converted to Wetlands | 0.000 | NO | NO | NO | NO | NO |
| 3.B.4.b.i - Land converted for peat extraction | NA | NO | NO | NO | NO | NO |
| 3.B.4.b.ii - Land converted to flooded land | NO | NO | NO | NO | NO | NO |
| 3.B.4.b.iii - Land converted to other wetlands | NA | NO | NO | NO | NO | NO |
| 3.B.5 - Settlements | 12.771 | NA | NA | NO | NO | NO |
| 3.B.5.a - Settlements Remaining Settlements | NO | NA | NA | NO | NO | NO |
| 3.B.5.b - Land Converted to Settlements | 12.771 | NA | NA | NO | NO | NO |
| 3.B.5.b.i - Forest Land converted to Settlements | 12.771 | NA | NA | NO | NO | NO |
| 3.B.5.b.ii - Cropland converted to Settlements | 0.000 | NA | NA | NO | NO | NO |
| 3.B.5.b.iii - Grassland converted to Settlements | NO | NA | NA | NO | NO | NO |
| 3.B.5.b.iv - Wetlands converted to Settlements | NO | NA | NA | NO | NO | NO |
| 3.B.5.b.v - Other Land converted to Settlements | NO | NA | NA | NO | NO | NO |
| 3.B.6 - Other Land | NO | NO | NO | NO | NO | NO |
| 3.B.6.a - Other land Remaining Other land | NO | NO | NO | NO | NO | NO |
| 3.B.6.b - Land Converted to Other land | NO | NO | NO | NO | NO | NO |
| 3.B.6.b.i - Forest Land converted to Other Land | NO | NO | NO | NO | NO | NO |
| 3.B.6.b.ii - Cropland converted to Other Land | NO | NO | NO | NO | NO | NO |
| 3.B.6.b.iii - Grassland converted to Other Land | NO | NO | NO | NO | NO | NO |
| 3.B.6.b.iv - Wetlands converted to Other Land | NO | NO | NO | NO | NO | NO |
| 3.B.6.b.v - Settlements converted to Other Land | NO | NO | NO | NO | NO | NO |
| 3.C - Aggregate sources and non-CO2 emissions sources on land (2) | 1.256 | 22.801 | 7.746 | 5.426 | 349.270 | NO |

| Categories | Net $CO_2$ emissions / removals | Emissions (Gg) | | | | |
|---|---|---|---|---|---|---|
| | | $CH_4$ | $N_2O$ | NOx | CO | NMVOCs |
| 3.C.1 - Emissions from biomass burning | 0.000 | 22.801 | 0.673 | 5.426 | 349.270 | NO |
| 3.C.1.a - Biomass burning in forest lands | NA | 22.759 | 0.669 | 5.355 | 348.086 | NO |
| 3.C.1.b - Biomass burning in croplands | NA | NO | NO | NO | NO | NO |
| 3.C.1.c - Biomass burning in grasslands | NA | 0.042 | 0.004 | 0.071 | 1.184 | NO |
| 3.C.1.d - Biomass burning in all other land | NA | NO | NO | NO | NO | NO |
| 3.C.2 - Liming | NO | NA | NA | NA | NA | NA |
| 3.C.3 - Urea application | 1.256 | NA | | NA | NA | NA |
| 3.C.4 - Direct N2O Emissions from managed soils (3) | NA | NA | 6.499 | NA | NA | NA |
| 3.C.5 - Indirect N2O Emissions from managed soils | NA | NA | 0.106 | NA | NA | NA |
| 3.C.6 - Indirect N2O Emissions from manure management | NA | NA | 0.468 | NA | NA | NA |
| 3.C.7 - Rice cultivations | NA | NO | NA | NA | NA | NA |
| 3.C.8 - Other (please specify) | NE | NO | NO | NA | NA | NA |
| 3.D - Other | -90.347 | NO | NO | NO | NO | NO |
| 3.D.1 - Harvested Wood Products | -90.347 | NA | NA | NA | NA | NA |
| 3.D.2 - Other (please specify) | NO | NO | NO | NO | NO | NO |

# 7. Waste

## 7.1. Description of Waste Sector

In Namibia, solid waste is generated by domestic, industrial, commercial and agricultural activities whereas wastewater is generated mostly through domestic, industrial and commercial activities. As in other countries, waste generation is directly related to population growth, industrialization rate and urbanization trend, the latter being an important impacting factor. GHG emission in the waste sector is also affected by the type of disposal mechanisms as well as the level of management exercised.

During the period under review, the waste categories from which emission data were captured were as follows:

- 4.A.3 - Uncategorised Waste Disposal Sites;
- 4.C.2 - Open Burning of Waste;
- 4.D.1 - Domestic Wastewater Treatment and Discharge; and
- 4.D.2 - Industrial Wastewater Treatment and Discharge.

### Uncategorised Waste Disposal Sites

Waste collection is mostly practised in urban areas. There are three landfill sites in the country, one at Kupferberg in the Khomas region for the disposal of general and hazardous waste generated within the City of Windhoek area of jurisdiction, and two in the region of Erongo which receive waste from Swakopmund and Walvis Bay. Waste from other towns and municipalities of the country is disposed of in open dump sites. Since there is no data on division of managed/unmanaged waste disposal systems, the classification used in this report for Solid Waste Disposal will be Uncategorised Waste Disposal Sites (4.A.3).

Waste generation rates varied between regions with the population living in urban areas having a higher generation rate than in rural areas. It is estimated that the average rural inhabitant generated 0.163 t of household waste per annum in 2016. The per capita rate of waste generation in urban high and urban low regions was estimated to be 51% and 34% respectively higher than that of rural areas.

It is estimated that the waste and garbage of about 57% of Namibian population was sent to waste disposal sites in 2016. These wastes are generated by 48% of the population who live in urban areas. The remaining waste generated by the rural population is open burned.

### Open Burning of Waste

It is estimated that at national level, the waste and garbage of some 43% of all household wastes were open burned in 2016. This is assumed to be occurring in rural areas primarily where 54% of the population lived in 2016. Open burning of waste is prohibited in urban areas and it is assumed not to occur.

### Domestic Wastewater Treatment and Discharge

The rate of use of population by type of toilet facility for the year 2016 varied between 84% in the urban high areas, 54% in urban low and 23% in rural regions (Table 7.2). At the country level, a notable fact is that a substantial portion of the population did not have access to any toilet facility in 2016. In urban high areas, 78% of residents had access to a centralized system, while only 43% of the urban low were connected to that type of wastewater management system (Table 7.2). The other common types of sewage systems used are latrines and septic tanks. The majority of the population in the rural areas did not have access to a toilet facility with only 23 % of them having access to such amenities, latrines being the most common type.

### Industrial Wastewater Treatment and Discharge

Industrial wastewater of relevance to GHG emissions originates mainly from such activities as fish processing, slaughterhouses, meat conditioning, tanneries and breweries. Due to unavailability of data, only the meat sector and fish processing are covered in this inventory. It should be noted that these two activities account for a major part of industrial wastewater in the country.

## 7.2. Methods

GHG emissions originating from the Waste Sector were estimated following a Tier 1 methodological approach as per the IPCC 2006 Guidelines for National GHG Inventories and computed using the IPCC Inventory Software.

## 7.3. Activity Data

### 7.3.1. Solid waste

Data from municipal councils coupled with population census statistics were first used to estimate solid waste generation for "high-income" urban and "low-income" urban regions for 2010. The need for this categorization has been prompted by the sustained and significant population migration from rural to urban regions with the emergence of fast expanding suburbs to the main cities where the dwellers' lifestyle is of the urban type with a relatively lower purchasing power.

Estimates of solid waste generation for rural regions for 2010 were subsequently worked out by discounting solid wastes which are typically generated by urban dwellers from the landfills data available on waste characterization. These solid waste generation potentials were also compared with those in the 2006 IPCC Guidelines (Volume 5: Waste, Page 2.5, Table 2.1).

Using the 2001, 2006 and 2011 Population and Housing Census Reports (interpolated or extrapolated for non-census years) and other data sources such as the FAO, adjusting for socio-economic factors and extrapolating waste generation from Windhoek data, estimates for solid waste generation were calculated for the period 1995 to 2016. This dataset was extrapolated back to 1990. Municipal waste data is provided in Table 7.1.

The process of calculating solid waste generation was not straightforward because of the lack of data. Furthermore, no official data was available on waste categorization which would have enabled more accurate estimations of GHG emissions. Thus, all the waste from Urban regions were considered as sent to solid waste disposal sites while 80 % of the waste from the rural regions were open burned.

The amount of sludge generated per capita for 2010 was estimated using that year's data for Windhoek City Council. Using this factor and urban population, the amount of sludge generated for the period 1990 to 2016 was then estimated for the other urban areas. AD for the period 1990 to 2016 is given in Table 7.1.

**Table 7.1 - Activity data for MSW in Waste sector (1990 - 2016)**

| | Municipal Solid Waste (MSW) (t) | | | Other waste sent to MSW (Gg) | |
|---|---|---|---|---|---|
| Year | Urban high | Urban low | Rural | Sludge | Industrial waste |
| 1990 | - | 38.57 | 66.71 | 0.68 | 21.45 |
| 1991 | - | 40.41 | 68.93 | 0.72 | 22.42 |
| 1992 | - | 43.04 | 71.63 | 0.74 | 23.43 |
| 1993 | - | 45.82 | 74.42 | 0.77 | 24.49 |
| 1994 | - | 48.77 | 77.32 | 0.80 | 25.60 |
| 1995 | - | 51.89 | 80.33 | 0.83 | 26.76 |
| 1996 | - | 55.20 | 83.45 | 0.87 | 27.97 |
| 1997 | - | 58.71 | 86.68 | 0.90 | 29.24 |
| 1998 | - | 62.42 | 90.04 | 0.93 | 30.56 |
| 1999 | - | 66.35 | 93.52 | 0.97 | 31.94 |
| 2000 | - | 70.50 | 97.14 | 1.00 | 33.39 |
| 2001 | 40.28 | 39.22 | 100.88 | 1.57 | 34.90 |
| 2002 | 44.04 | 43.16 | 105.82 | 1.65 | 36.48 |
| 2003 | 48.07 | 47.48 | 110.97 | 1.72 | 38.13 |
| 2004 | 52.4 | 52.23 | 116.34 | 1.80 | 39.86 |
| 2005 | 57.04 | 57.43 | 121.94 | 1.88 | 41.66 |
| 2006 | 62.01 | 63.13 | 127.79 | 1.96 | 43.55 |
| 2007 | 67.33 | 69.37 | 133.87 | 2.04 | 45.52 |
| 2008 | 73.04 | 76.20 | 140.21 | 2.13 | 47.58 |
| 2009 | 79.14 | 83.68 | 146.81 | 2.22 | 49.73 |
| 2010 | 85.67 | 91.85 | 153.67 | 2.31 | 51.98 |
| 2011 | 92.66 | 100.78 | 160.81 | 2.40 | 54.33 |
| 2012 | 97.45 | 107.19 | 184.32 | 2.50 | 58.27 |
| 2013 | 102.4 | 113.89 | 187.14 | 2.60 | 59.05 |
| 2014 | 107.51 | 120.91 | 189.89 | 2.70 | 59.82 |
| 2015 | 112.77 | 128.25 | 192.53 | 2.80 | 60.57 |
| 2016 | 118.19 | 135.94 | 195.09 | 2.91 | 61.33 |

### 7.3.2. Wastewater

The actual amount of domestic wastewater generated was not available at country level. However, the different types and usage levels of treatment or discharge as per the NPHC 2001, 2006 and 2011 census reports were used as well as the respective IPCC 2006 Guidelines (Vol 5.3 Ch 3 Table 3.1) default MCFs. The use the different waste systems have been harmonized into three main types: Centralized aerobic, septic tank and latrines. The timeseries of the evolution of the three types of sewage systems and the use rate is given in Table 7.2.

**Table 7.2 - Timeseries for use rate of different sewage systems (1990 - 2016)**

| Year | Urban high | | | Urban low | | | Rural | | |
|---|---|---|---|---|---|---|---|---|---|
| | Centralized aerobic | Latrine | Septic Tank | Centralized aerobic | Latrine | Septic Tank | Centralized aerobic | Latrine | Septic |
| 1990 | 0.736 | 0.042 | 0 | 0.924 | 0.106 | 0.022 | 0.107 | 0.091 | 0.010 |
| 1991 | 0.738 | 0.041 | 0 | 0.909 | 0.105 | 0.022 | 0.107 | 0.092 | 0.011 |
| 1992 | 0.740 | 0.040 | 0 | 0.895 | 0.104 | 0.023 | 0.106 | 0.092 | 0.011 |
| 1993 | 0.741 | 0.040 | 0 | 0.880 | 0.103 | 0.024 | 0.105 | 0.093 | 0.012 |

| Year | Urban high | | | Urban low | | | Rural | | |
|---|---|---|---|---|---|---|---|---|---|
| | Centralized aerobic | Latrine | Septic Tank | Centralized aerobic | Latrine | Septic Tank | Centralized aerobic | Latrine | Septic |
| 1994 | 0.743 | 0.039 | 0.002 | 0.866 | 0.102 | 0.025 | 0.104 | 0.094 | 0.013 |
| 1995 | 0.744 | 0.039 | 0.003 | 0.851 | 0.101 | 0.025 | 0.104 | 0.095 | 0.014 |
| 1996 | 0.746 | 0.038 | 0.005 | 0.836 | 0.100 | 0.026 | 0.103 | 0.096 | 0.015 |
| 1997 | 0.748 | 0.037 | 0.007 | 0.822 | 0.099 | 0.027 | 0.102 | 0.097 | 0.016 |
| 1998 | 0.749 | 0.037 | 0.008 | 0.807 | 0.098 | 0.027 | 0.101 | 0.098 | 0.016 |
| 1999 | 0.751 | 0.036 | 0.010 | 0.793 | 0.097 | 0.028 | 0.101 | 0.099 | 0.017 |
| 2000 | 0.752 | 0.036 | 0.011 | 0.791 | 0.097 | 0.029 | 0.102 | 0.099 | 0.017 |
| 2001 | 0.754 | 0.035 | 0.013 | 0.741 | 0.095 | 0.028 | 0.096 | 0.102 | 0.020 |
| 2002 | 0.756 | 0.034 | 0.015 | 0.756 | 0.095 | 0.030 | 0.099 | 0.101 | 0.019 |
| 2003 | 0.757 | 0.034 | 0.016 | 0.738 | 0.094 | 0.031 | 0.098 | 0.102 | 0.020 |
| 2004 | 0.759 | 0.033 | 0.018 | 0.720 | 0.093 | 0.031 | 0.097 | 0.103 | 0.021 |
| 2005 | 0.760 | 0.033 | 0.019 | 0.702 | 0.092 | 0.032 | 0.096 | 0.105 | 0.022 |
| 2006 | 0.762 | 0.032 | 0.021 | 0.749 | 0.092 | 0.036 | 0.104 | 0.102 | 0.020 |
| 2007 | 0.764 | 0.031 | 0.023 | 0.667 | 0.090 | 0.033 | 0.093 | 0.107 | 0.024 |
| 2008 | 0.765 | 0.031 | 0.024 | 0.649 | 0.089 | 0.033 | 0.092 | 0.108 | 0.025 |
| 2009 | 0.767 | 0.030 | 0.026 | 0.631 | 0.088 | 0.034 | 0.091 | 0.109 | 0.026 |
| 2010 | 0.768 | 0.030 | 0.027 | 0.613 | 0.087 | 0.034 | 0.090 | 0.110 | 0.027 |
| 2011 | 0.770 | 0.029 | 0.029 | 0.563 | 0.085 | 0.033 | 0.084 | 0.113 | 0.030 |
| 2012 | 0.772 | 0.028 | 0.031 | 0.543 | 0.084 | 0.033 | 0.082 | 0.115 | 0.033 |
| 2013 | 0.774 | 0.027 | 0.033 | 0.516 | 0.083 | 0.033 | 0.080 | 0.116 | 0.034 |
| 2014 | 0.775 | 0.027 | 0.034 | 0.488 | 0.082 | 0.033 | 0.077 | 0.118 | 0.036 |
| 2015 | 0.777 | 0.026 | 0.036 | 0.046 | 0.080 | 0.033 | 0.074 | 0.120 | 0.038 |
| 2016 | 0.779 | 0.025 | 0.038 | 0.432 | 0.079 | 0.033 | 0.071 | 0.122 | 0.040 |

Coupled with the use rate, the fraction of population living in the 3 different zones, urban high, urban low and rural was also generated in a timeseries for input in the software. The evolution of the different population fraction used is given in Table 7.3.

**Table 7.3 - Fraction of population living in the different areas (1990 - 2016)**

| Year | Fraction population | | |
|---|---|---|---|
| | Urban high | Urban low | Rural |
| 1990 | 0.124 | 0.153 | 0.723 |
| 1991 | 0.127 | 0.153 | 0.723 |
| 1992 | 0.130 | 0.153 | 0.720 |
| 1993 | 0.133 | 0.155 | 0.715 |
| 1994 | 0.136 | 0.159 | 0.705 |
| 1995 | 0.139 | 0.161 | 0.700 |
| 1996 | 0.142 | 0.163 | 0.695 |
| 1997 | 0.145 | 0.165 | 0.690 |
| 1998 | 0.148 | 0.167 | 0.685 |
| 1999 | 0.151 | 0.169 | 0.680 |
| 2000 | 0.154 | 0.166 | 0.680 |
| 2001 | 0.157 | 0.173 | 0.670 |
| 2002 | 0.161 | 0.179 | 0.660 |
| 2003 | 0.165 | 0.185 | 0.650 |
| 2004 | 0.169 | 0.191 | 0.640 |

| Year | Fraction population | | |
|---|---|---|---|
| | Urban high | Urban low | Rural |
| 2005 | 0.173 | 0.197 | 0.630 |
| 2006 | 0.177 | 0.203 | 0.620 |
| 2007 | 0.180 | 0.210 | 0.610 |
| 2008 | 0.184 | 0.216 | 0.600 |
| 2009 | 0.187 | 0.223 | 0.590 |
| 2010 | 0.190 | 0.230 | 0.580 |
| 2011 | 0.193 | 0.237 | 0.570 |
| 2012 | 0.196 | 0.244 | 0.560 |
| 2013 | 0.200 | 0.250 | 0.550 |
| 2014 | 0.203 | 0.257 | 0.540 |
| 2015 | 0.206 | 0.264 | 0.530 |
| 2016 | 0.209 | 0.271 | 0.520 |

The protein content in the diet of the population is also needed as an AD for calculations of emissions from domestic wastewater. FAO data for years 1999 to 2011 are available. Trending technique was used to generate the data for the periods 1990 to 1998 and 2012 to 2016. Table 7.4 summarizes the data for protein intake by the population.

**Table 7.4 - Annual per capita protein intake**

| Year | Protein intake (kg per capita / year) |
|---|---|
| 1990 | 26.645 |
| 1991 | 26.353 |
| 1992 | 26.061 |
| 1993 | 25.477 |
| 1994 | 25.477 |
| 1995 | 25.185 |
| 1996 | 24.893 |
| 1997 | 24.601 |
| 1998 | 24.309 |
| 1999 | 24.090 |
| 2000 | 23.725 |
| 2001 | 23.360 |
| 2002 | 22.995 |
| 2003 | 22.995 |
| 2004 | 22.995 |
| 2005 | 22.995 |
| 2006 | 23.360 |
| 2007 | 22.995 |
| 2008 | 22.265 |
| 2009 | 21.900 |
| 2010 | 21.535 |
| 2011 | 21.170 |
| 2012 | 20.659 |
| 2013 | 20.221 |
| 2014 | 19.783 |
| 2015 | 19.345 |

| Year | Protein intake (kg per capita / year) |
|---|---|
| 2016 | 18.907 |

Exploitable data on industrial waste water production were available only for the meat (beef and sheep) (source: Meatco factories, Agric Stats 2009, AGRA) and fish (Pilchards and Mackerel processing) (source: Ministry of Fisheries, Annual report 2005, Source for 2006 to 2010 - Preliminary census 2011 data). The total meat industry product and the amount of wastewater as provided by local authorities were used in conjunction with the respective IPCC 2006 Guidelines (Vol 5.3 Ch 3 Table 3.1) defaults for calculation of emissions. AD for industrial wastewater is given in Table 7.5.

**Table 7.5 - Activity data for industrial wastewater (1990 - 2016)**

| Year | Fish processing (t) | Meat and Poultry (t) |
|---|---|---|
| 1990 | 498,000 | 40,441 |
| 1991 | 502,000 | 46,310 |
| 1992 | 508,000 | 46,617 |
| 1993 | 490,600 | 50,061 |
| 1994 | 475,000 | 46,868 |
| 1995 | 409,000 | 43,051 |
| 1996 | 321,000 | 43,813 |
| 1997 | 338,000 | 28,311 |
| 1998 | 323,000 | 36,629 |
| 1999 | 330,000 | 43,575 |
| 2000 | 362,805 | 44,822 |
| 2001 | 326,008 | 42,135 |
| 2002 | 263,343 | 47,869 |
| 2003 | 383,002 | 46,104 |
| 2004 | 339,010 | 46,147 |
| 2005 | 352,828 | 53,176 |
| 2006 | 312,294 | 46,395 |
| 2007 | 225,182 | 46,219 |
| 2008 | 205,751 | 47,537 |
| 2009 | 235,188 | 50,751 |
| 2010 | 240,518 | 48,622 |
| 2011 | 230,440 | 44,001 |
| 2012 | 313,193 | 43,394 |
| 2013 | 230,270 | 43,080 |
| 2014 | 208,634 | 44,093 |
| 2015 | 255,485 | 46,698 |
| 2016 | 208,634 | 37,700 |

## 7.4. Emission factors

In the absence of country specific EFs, the default values provided within the IPCC Inventory Software and IPCC 2006 Guidelines (Vol_5_Ch6_Wastewater Table 6.8 and Table 6.9) were used for estimating GHG emissions.

## 7.5. Emission estimates

### 7.5.1. Aggregated emissions by gas for inventory year 2016

In 2016, a total of 166.7 Gg $CO_2$-eq were emitted from sector Waste. The most important contributor to emissions was $CH_4$ with 137.2 Gg $CO_2$-eq, representing 82 % of emissions, followed by $N_2O$ with 27.1 Gg $CO_2$-eq (16 % of emissions) and $CO_2$ with 2.4 Gg $CO_2$-eq (2% of emissions) (Figure 7.1).

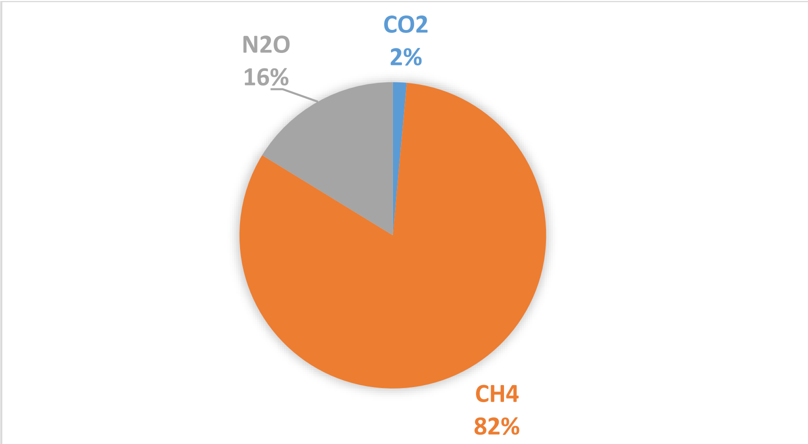


Figure 7.1- Share of emissions by gas for the Waste Sector (2016)

### 7.5.2. Emissions of indirect gases and $SO_2$ for inventory year 2016

In 2016 sector Waste also emitted 8.7 Gg of CO, 0.59 Gg of NMVOCs, 0.50 Gg $NO_x$, 0.09 Gg $N_2O$ and 0.02 Gg $SO_2$ (Figure 7.2).

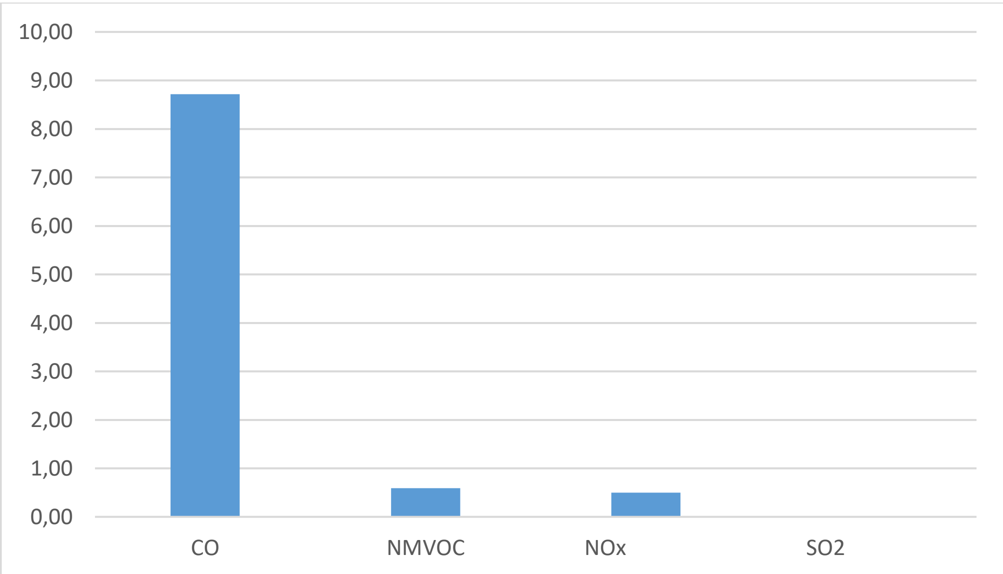


Figure 7.2- Emissions of $N_2O$, $NO_x$, NMVOCs and $SO_2$ from waste Sector (2016)

### 7.5.3. Emission trend by gas for the period 1990 to 2016

Analysis of aggregated emission trend by gas (Figure 7.3) shows the following:

(i) $CH_4$ was the main contributor to emissions throughout the time series with emissions increasing by 175% over the period.

(ii) $N_2O$ was the second contributor to emissions which increased by 23% from 1990 to 2016.

(iii) $CO_2$, even if emitted at a much lesser extent, increased by 3 times over the period 1990 to 2016.

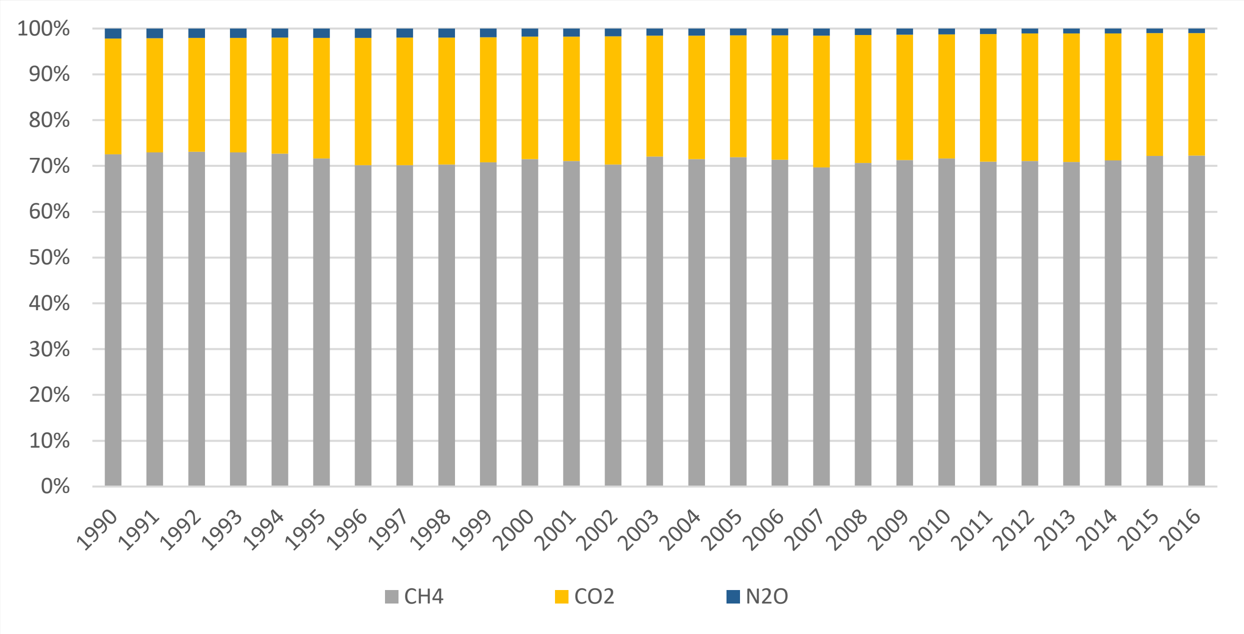


**Figure 7.3- Percentage distribution of emissions for waste Sector (1990 - 2016)**

### 7.5.4. Emissions by waste categories for inventory year 2016

Out of the total emissions of 166.7 Gg $CO_2$-eq recorded in 2016, Solid Waste Disposal was the most important contributor with 89 Gg $CO_2$-eq followed by Wastewater Treatment and Discharge with 49.8 Gg $CO_2$-eq, Open Burning of Waste with 27.9 Gg (16.9%). For the latter, Domestic Wastewater Treatment and Discharge contributed 36.0 Gg $CO_2$-eq and Industrial Wastewater Treatment and Discharge contributed 13.8 Gg $CO_2$-eq (Table 7.6).

During the same inventory year, sector Waste also emitted 0.50 Gg $NO_x$, 8.71 Gg CO, 0.59 Gg NMVOCs and 0.02 Gg $SO_2$.

**Table 7.6 - Emissions by gas and category from Waste sector for inventory year 2016**

| Categories | Emissions (Gg $CO_2$ eq) | | | | Emissions (Gg) | | | |
|---|---|---|---|---|---|---|---|---|
| | $CO_2$ | $CH_4$ | $N_2O$ | Total $CO_2$ eq | $NO_x$ | CO | NMVOCs | $SO_2$ |
| 4 - Waste | 2.4 | 137.2 | 27.1 | 166.7 | 0.50 | 8.71 | 0.59 | 0.02 |
| 4.A - Solid Waste Disposal | - | 89.0 | - | 89.0 | - | - | 0.38 | - |
| 4.A.2 - Unmanaged Waste Disposal Sites | - | 89.0 | - | 89.0 | - | - | 0.38 | - |
| 4.C - Incineration and Open Burning of Waste | 2.4 | 21.3 | 4.1 | 27.9 | 0.49 | 8.64 | 0.19 | 0.02 |
| 4.C.2 - Open Burning of Waste | 2.4 | 21.3 | 4.1 | 27.9 | 0.49 | 8.64 | 0.19 | 0.02 |
| 4.D - Wastewater Treatment and Discharge | - | 26.9 | 22.9 | 49.8 | - | - | 1.00E-06 | - |
| 4.D.1 - Domestic Wastewater Treatment and Discharge | | 13.0 | 22.9 | 36.0 | - | - | 8.00E-07 | - |
| 4.D.2 - Industrial Wastewater treatment and Discharge | - | 13.8 | - | 13.8 | - | - | 2.00E-07 | - |

Table 7.7 - Sectoral Table Waste sector (Inventory Year: 2016)

| Categories | Gg | | | | | | |
|---|---|---|---|---|---|---|---|
| | $CO_2$ | $CH_4$ | $N_2O$ | NOx | CO | NMVOCs | SO2 |
| 4 - Waste | 2.422 | 6.533 | 0.087 | 0.496 | 8.714 | 0.588 | 0.017 |
| 4.A - Solid Waste Disposal | 0.000 | 4.239 | 0.000 | 0.000 | 0.000 | 0.396 | 0.000 |
| 4.A.1 - Managed Waste Disposal Sites | NA | 0.000 | NA | NO | NO | NO | NA |
| 4.A.2 - Unmanaged Waste Disposal Sites | NA | 0.000 | NA | NO | NO | 0.396 | NA |
| 4.A.3 - Uncategorised Waste Disposal Sites | NA | 0.000 | NA | NO | NO | 0.000 | NA |
| 4.B - Biological Treatment of Solid Waste | NA | NO | NO | NO | NO | NO | NA |
| 4.C - Incineration and Open Burning of Waste | 2.422 | 1.014 | 0.013 | 0.496 | 8.714 | 0.192 | 0.017 |
| 4.C.1 - Waste Incineration | NE | NE | NE | NE | NE | NE | NE |
| 4.C.2 - Open Burning of Waste | 2.422 | 1.014 | 0.013 | 0.496 | 8.714 | 0.192 | 0.017 |
| 4.D - Wastewater Treatment and Discharge | NA | 1.280 | 0.074 | NO | NO | 0.000 | 0.000 |
| 4.D.1 - Domestic Wastewater Treatment and Discharge | NA | 0.620 | 0.074 | NO | NO | 0.000 | NA |
| 4.D.2 - Industrial Wastewater Treatment and Discharge | NA | 0.659 | NA | NO | NO | 0.000 | NA |
| 4.E - Other (please specify) | NO | NO | NO | NO | NO | NO | NO |

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