REPUBLIC OF NAMIBIA

Fourth National Communication to the United Nations Framework Convention on Climate Change

March 2020

REPUBLIC OF NAMIBIA

Fourth National Communication to the United Nations Framework Convention on Climate Change

March 2020

MET, Private bag 13306, Windhoek, Namibia
Phone: +264612842701

Contributors:
Climagric Ltd – National Circumstances, GHG Inventory, Mitigation and Other Information Relevant to the Convention chapters
Afromach Investments (PTY) Ltd – Vulnerability and Adaptation chapter

Foreword

On behalf of the Government of the Republic of Namibia, it is an honour and a privilege for me to present Namibia's Fourth National Communication in fulfilment of its obligations as a Non-Annex I Party to the United Nations Framework Convention on Climate Change as mandated by Article 4 & 12 of the Convention.

Namibia ratified the UNFCCC in 1995 and thus became obligated to prepare and submit national communications, Biennial Update Reports and NDCs. Namibia also ratified the Paris Agreement in 2016. As a signatory Party to the convention, Namibia has prepared and submitted three 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 BUR and third BUR in 2016 and 2018 respectively. Furthermore, Namibia prepared and submitted its Nationally Determined Contributions (NDC) in 2015, which is currently under revision. Namibia is also currently busy with its Fourth Biennial Update Report (BUR4) which will be submitted to the UNFCCC in 2020.

Namibia is one of the countries who has been so far compliant in terms of its reporting obligations. The NC4 will provide an update on the national Greenhouse Gas (GHG) inventory, its mitigation policy, the Vulnerability and Adaptation status along with Other Information Relevant to the Convention and Gaps, Constraints and Needs. Namibia is one of the first countries to have gone through the first round of the International Consultation Analysis (ICA) process of its first BUR and also two more rounds on its BUR2 and BUR3.

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 and it covers the thematic areas mitigation, adaptation and related cross cutting issues. The strategy is currently undergoing a review.

Hon. Pohamba Shifeta

Minister of Environment and Tourism

Acknowledgements

This report received contributions from various Departments of the Ministries, Private Sector Institutions including social and community organizations of the Republic of Namibia. Their contributions are gratefully acknowledged. Namibia also acknowledges the financial contribution made by the Global Environment Facility through the UNDP country office as implementing Agency. Namibia also wishes to put on record the support provided by the Consultants of CLIMAGRIC Ltd, and AFROMACH Investments (PTY) Ltd for capacity building of the national experts, production of the chapters on various themes and CLIMAGRIC Ltd. for compilation of the Fourth National Communication Report. The main contributors are listed below.

PROJECT TEAM AND CONTRIBUTORS:

- Overall supervision by Mr. Teofilus Nghitila
- Project Supervisor Mr. Petrus Muteyauli
- Project Coordinator Mr. Reagan Sibanga Chunga

MAIN CONTRIBUTORS:

- Ministry of Environment and Tourism
- Ministry of Mines and Energy
- Ministry of Works and Transport - Civil Aviation Office
- Ministry of Agriculture, Water Affairs and Forestry
- Ministry of Industrialization and SMEs
- Ministry of Fisheries and Marine Resources
- National Planning Commission
- NamPower
- Namibia Statistics Agency
- Namibia Energy Institute
- City councils and municipalities
- TransNamib Holdings Ltd
- Namibia Airports Company
- Petroleum products dealers
- Namport
- Electricity Control Board
- Meatco Namibia

Table of Contents

List of Tables

List of Figures

Abbreviations and acronyms

Abbreviation / Acronym	Definition
°C	degree Celsius
AD	Activity Data
AFOLU	Agriculture, Forest and Other Land Use
AIDS	Acquired Immune Deficiency Syndrome
ALU	Agriculture and Land Use National Greenhouse Gas Inventory Software
AR	Assessment Report
ASSAR	Adaptation at Scale in Semi-Arid Regions
BAU	Business as usual
Bm	biomass
BUR	Biennial Update Report
BTR	Biennial Transparency Report
C	carbon
CBO	Community Based Organisation
CBS	Central Bureau of Statistics
CCSAP	Climate Change Strategy and Action Plan
CCU	Climate Change Unit
CDC	Centre for Disease Control and Prevention
CH_4	methane
CNG	Compressed Natural Gas
CO	carbon monoxide
CO_2	carbon dioxide
CO_2-eq	carbon dioxide equivalent
COP	Conference of Parties
CRU	Climatic Research Unit
CS	Country-specific
CSIR	Council for Scientific and Industrial Research
CSO	Civil Society Organisation
dbh	diameter breast height
DE	Digestible Energy
DEA	Department of Environmental Affairs
DoF	Directorate of Forestry
DRFN	Desert Research Foundation Namibia
ECB	Electricity Control Board
EF	Emission Factor
EMEP	European Monitoring and Evaluation Program
ESKOM	Electricity Supply Commission
FANRPAN	Food, Agriculture and Natural Resources Policy Analysis Network
FAO	Food and Agricultural Organisation
FL	Forest Land
FOLU	Forestry and Other Land Use
FRA	Forest Resource Assessments
GCM	General Circulation Model
GDP	Gross Domestic Product
GEF	Global Environment Facility
Gg	Gigagram
GHG	GreenHouse Gas
GHGIMS	Greenhouse Gas Inventory Management System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GL	Guideline

Abbreviation / Acronym	Definition
GNDI	Gross National Disposable Income
GNI	Gross National Income
GPG	Good Practice Guidance
GRN	Government of the Republic of Namibia
GVM	Gross Vehicle Mass
GWH	Gigawatt Hour
GWP	Global Warming Potential
ha	Hectare
HAC	High Activity Clay
HFCs	hydrofluorocarbons
HIV	Human Immunodeficiency Virus
HPP	Harambee Prosperity Plan
HWP	Harvested Wood Products
INC	Initial National Communication
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
ITCZ	Inter-Tropical Convergence Zone
Iv	Biomass growth increment
IWRM	Integrated Water Resources Management
KCA	Key Category Analysis
kg	Kilogram
km	kilometre
LAC	Low Activity Clay
LPG	Liquefied Petroleum Gas.
M	Million
m	metre
m^3	cubic metre
M&E	Monitoring and Evaluation
m/s	metre per second
mamsl	metre above mean sea level
MAWF	Ministry of Agriculture, Water Affairs and Forestry
MCF	Methane Conversion Factor
MET	Ministry of Environment and Tourism
mm	millimeter
MMS	Manure Management System
MoU	Memorandum of Understanding
MRV	Measuring, Reporting and Verification
MSW	Municipal Solid Waste
MW	MegaWatt
MWG	Mitigation Working Group
N	Nitrogen
N$	Namibian dollar
N_2O	Nitrous oxide
NAFIN	National Alliance for Improved Nutrition
NAMA	Nationally Appropriate Mitigation Action
NAMPHIA	Namibia Population-based HIV Impact Assessment
NAMREP	Namibian Renewable Energy Programme
NAP	National Agricultural Policy
NATIS	A subdivision of the Transport Information and Regulatory Services of the Namibian Road Authority
NC	National Communication
NC3	Third National Communication
NC4	Fourth National Communication

Abbreviation / Acronym	Definition
NCCC	National Climate Change Committee
NCCSAP	Namibia Climate Change Strategy and Action Plan
NCCVI	Namibia Climate Change Vulnerability Index
NDC	Nationally Determined Contributions
NDP	National Development Plan
NDP5	Fifth National Development Plan
NEEP	Namibia Energy Efficiency Programme
NEI	Namibia Energy Institute
NFI	National Forest Inventory
NGO	Non-Governmental Organization
NHIES	Namibia Household Income & Expenditure Survey
NIDS	Namibia Inter-censal Demographic Survey
NIIP	National Inventory Improvement Plan
NIR	National Inventory Report
NIRP	National Integrated Resource Plan
NMVOC	Non-Methane Volatile Organic Compound
NO_x	Nitrogen Oxides
NPC	National Planning Commission
NPCC	National Policy on Climate Change
NSA	Namibia Statistics Agency
NVDCP	National Vector-Born Disease Control Program
ODS	Ozone Depleting Substances
OGEMP	Off Grid Energy Master Plan
OL	Other Land
OPM	Office of the Prime Minister
OWL	Other Wooded Land
PA	Paris Agreement
PFCs	Perfluorocarbons
PRP	Pasture-Range-Paddock
QA	Quality Assurance
QC	Quality Control
RAC	Refrigeration and Air-Conditioning
RCM	Regional Climate Model
RCMRD	Regional Centre for Mapping Resource for Development
REDD(+)	Reducing Emissions from Deforestation and Degradation
REEEI	Renewable Energy & Energy Efficiency Institute
SACU	South African Customs Union
SADC	Southern Africa Development Community
SAPP	South African Power Pool
SF_6	sulphur hexafluoride
SME	Small and Medium Enterprises
SNC	Second National Communication
SO_2	Sulphur dioxide
t	Tonne
TACCC	Transparent, Accurate, Complete, Consistent and Comparable
TJ	Terajoule
TNC	Third national Communication
TTT	Tropical Temperate Troughs
UN	United Nations
UNAM	University of Namibia
UNDP	United Nations Development Program
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change

Abbreviation / Acronym	Definition
UNICEF	United Nations International Children's Emergency Fund
USD	United States Dollar
US-EPA	United States Environmental Protection Agency
V&A	Vulnerability and Adaptation
WHO	World Health Organization
WMO	World Meteorological Organization
WTTC	World Travel & Tourism Council
yr	Year
ZESCO	Zambia Electricity Supply Corporation

Executive Summary

ES 1. National Circumstances

Namibia's development is guided by its 5-year periods National Development Plans within its long-term National Policy Framework, Vision 2030, and recently by the Harambee Prosperity Plan (HPP). The country is currently in its Fifth National Development Plan (NDP5) that outlines a development strategy aiming at improving the living conditions of every Namibian through sustainable development and a low carbon economy.

Namibia ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1995 as a Non-Annex 1 Party, and as such, is obliged to report certain elements of information in accordance with Article 4, paragraph 1 of the Convention. In order to meet its reporting obligations, Namibia has submitted three national communications (NCs), three Biennial Update Reports (BURs), including three stand-alone National Inventory Reports (NIRs) and its Intended Nationally Determined Contributions (INDC), now NDC, making Namibia one of the most compliant non-Annex 1 parties to the convention.

The multi-sectoral National Climate Change Committee (NCCC), chaired by the Ministry of Environment and Tourism (MET), provided the overall oversight and advisory role for the implementation of the NC4 project. Like the previous NCs and BURs, NC4 was coordinated by the Climate Change Unit (CCU), under the Department of Environmental Affairs (DEA) of the MET.

The Cabinet of Namibia is the Government entity entrusted with the overall responsibility for the development of Policies, including those on The NCCC, comprising representatives of the various ministries and other stakeholders, was established in 1999 by a Cabinet directive to advise Cabinet on climate change issues, including reporting obligations. MET, the official government agency acting as national focal point of the Convention, is responsible for coordinating and implementing climate change activities, including the preparation of National Reports to enable the country meet its reporting obligations. This is done through the Climate Change Unit (CCU) established within the DEA. Being a formalized and multi-sectoral committee, the NCCC provides the necessary support to the CCU by advising and guiding it.

Namibia is situated in the southwestern region of the African continent and lies between latitude 17° and 29°S and longitude 11° and 26°E. The country covers a land area of 825 418 km^2 and has a 1500 km long coastline on the South Atlantic Ocean. It is sandwiched between Angola to the North and South Africa to the South and also borders with Zambia to the far North, and Botswana to the East.

Namibia is one of the biggest and driest countries in sub-Saharan Africa. It is characterized by high climatic variability in the form of persistent droughts, unpredictable and variable rainfall patterns, variability in temperatures and scarcity of water. The mean annual rainfall ranges from just above 600 mm in the Northeast to less than 25 mm in the Southwest and West of the country.

Namibia is characterized by high temperatures. Apart from the coastal zone, there is a marked seasonal temperature regime, with the highest temperatures occurring just before the wet season in the wetter areas or during the wet season in the drier areas. The lowest temperatures occur during the dry season months of June to August. Mean monthly minimum temperatures do not, on average, fall below 0°C.

From a hydrological point of view, Namibia is an arid, water deficient country. High solar radiation, low humidity and high temperature lead to very high evaporation rates, which vary between 3800 mm per annum in the south to 2600 mm per annum in the north. Over most of the country, potential evaporation is at least five times greater than average rainfall.

Wind speeds are generally low in Namibia, only at the coast do mean wind speeds exceed 3 m/s.

Namibia holds a remarkable variety of species, habitats and ecosystems ranging from deserts to subtropical wetlands and savannas. Namibia is one of the very few countries in Africa with internationally-recognized "biodiversity hotspot", the most significant one is the Sperrgebiet, in the Succulent Karoo floral kingdom, shared with South Africa. Namibian also hosts the world's largest populations of cheetah and free-roaming black rhino.

Despite its relatively modest contribution the GDP, agriculture remains a strategic sector as it impacts directly on the livelihood of more than 70% of the population and employs about one third of the workforce of Namibia. The sector is crucial in addressing the food security and livelihood concerns of a significant segment of the population. The production of white maize, wheat, pearl millet and livestock including cattle, goat and sheep is divided in the intensive commercial production units and the extensive communal production system. The commercial sector though occupying 44% of land involves only 10% of population while the communal sector occupies 41% of the land and involves 60% of the population.

Namibia has one of the most productive fishing grounds in the world, primarily due to the presence of the Benguela current. The commercial fishing and fish processing sectors significantly contribute to the economy in terms of employment, export earnings, and contribution to GDP. The sector is a substantial export earner, with over 85% of Namibia's fish output destined for international markets, contributing 15% of Namibia's total exports.

Namibia's unique landscapes and biodiversity support a rapidly developing tourism sector, its contribution estimated for 2016 at N$16.7 billion, equivalent to 10.5% of overall GDP and 101,000 jobs equivalent to 14.9% of total employment.

According to the state of community conservancy report of 2017, community conservation in Namibia covers 166,267 km^2, which is about 53.2% of communal land with an estimated 212,092 residents. At the end of 2017, there were 83 registered communal conservancies and one community conservation association in a national park, which is managed like a conservancy. Conservancies covered 163,151 km^2 which is equivalent to 19.8% of Namibia's total land surface (NACSO, 2017).

At the end of 2017 there were 32 registered community forests, covering a total of 30,828 km^2 of Namibia, 89% of which overlaps with conservancies. The Forestry Act of 2001 and the Forestry Amendment Act of 2005 enable the registration of community forests through a written agreement between the Directorate and a committee elected by a community with traditional rights over a defined area of land. The agreement is based on an approved management plan that outlines the use of resources.

Namibia is known world-wide for producing gem quality rough diamonds, uranium oxide, special high-grade zinc and acid-grade fluorspar, as well as a producer of gold bullion, blister copper, lead concentrate, salt and dimension stone. According to the Chamber of Mines annual review report of 2018, mining is one of the major contributors of Namibia's national economy with 14% of the country's GDP in 2018.

Namibia's manufacturing sector is inhibited by its small domestic market, dependence on imported goods, limited supply of local capital, widely dispersed population, small skilled labour force and high relative wage rates, and subsidized competition from South Africa.

On the supply side, Namibia currently has three electricity power stations which translates to 380 MW capacity. Current local electricity peak demand stands at 656 MW, exceeding local generation capacity at 484 MW at peak (NDP5). Currently, Namibia imports most of this difference from South Africa and other Southern Africa Development Community (SADC) member states.

Namibia has a total road network of more than 64,189 km, including 5477 km of tarred roads which link the country to the neighbouring countries Angola, Botswana, South Africa, Zambia and Zimbabwe.

The country has two ports handling imported and exported merchandise and servicing the fishing industry. The only deep-sea harbour is Walvis Bay in the Erongo Region. The other harbour is Luderitz in the Karas Region.

Passenger transport is mainly carried out by minibuses and sedans and is increasing in intensity. For businesspeople and tourists, air travel has become a more important means of transport to bridge the long distances.

The railway network comprises 2382 km of narrow-gauge track with the main line running from the border with South Africa via Keetmanshoop to Windhoek, Okahandja, Swakopmund and Walvis Bay. Omaruru, Otjiwarongo, Otavi, Tsumeb and Grootfontein are connected to the northern branch of the railway network.

Namibia, as a medium income country with a growing wealthy urban middle class and significant urban drift, is feeling the pressure of amounts of waste generated on its facilities throughout the country and more especially in the urban areas. Solid municipal waste is dumped in landfills or open dumps while almost all urban settlements are connected to reticulated waste-water treatment systems. Management of the landfills and dumps are not at the highest standards and very often, the waste is burnt in the open dumps to reduce the volume and health risks. The ministry of environment and tourism, responsible for managing solid waste, has developed and is currently enforcing the solid waste management strategy in both rural and urban areas.

According to the National Accounts estimates, compiled by NSA in 2017 the domestic economy is estimated to have registered a contraction in real value added of 0.9% compared to a growth of 0.6% in 2016. The drop was attributed to a weak performance in the secondary and tertiary sectors, with declines in real value added of 6.7% and 1.4% respectively. However, on the backdrop of good rainfall and an increase in production of major export commodities, the primary industries registered a strong growth of 10.6% in real value added in 2017.

Over the period 2007 to 2017, Gross National Disposable Income (GNDI) has been consistently higher than the GNI because of net inflows in current transfers that have been influenced mainly by high SACU receipts. Gross National Income stood at N$ 173.88 billion in 2017 as compared to N$ 162.18 billion recorded in 2016, representing an increase of 7.2 percent in nominal terms. GNDI improved to N$ 191.95 billion in 2017 from N$ 178.79 billion of the preceding year.

According to the 2016 Namibia Inter-censal Demographic survey, the population of Namibia was estimated at 2,324,388 people. Woman outnumbered man with 1,194,634, compared to 1,129,754. A total of 43% of Namibia's population lived in urban areas with the remaining 57% in rural areas. The urban population grew by 49.7% between 2001 and 2011, while the rural population decreased by 1.4% over the same period.

Namibia's provision of health services is shared between the public and the private sector, the latter focusing on urban areas. Infant and child mortality is comparatively low, but the maternal mortality ratio has increased, even though over 70% of births are delivered in hospitals. General life expectancy has not improved, partly because of the HIV/AIDS epidemic. Malnutrition levels in children under the age of five years are as high as 38% in some regions. The five leading causes of inpatient deaths (all age groups) are HIV/AIDS, diarrhoea, tuberculosis, pneumonia and malaria.

ES 2. Greenhouse Gas Inventory

ES 2.1 The Inventory Process

ES 2.1.1 Overview of GHG Inventories

Under Article 4.1 (a) of the Convention, each party has to develop, periodically update, publish and make available to the Conference of the Parties, 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, to the extent its capacities permit, using comparable methodologies to be promoted and agreed upon by the Conference of the Parties.

This seventh GHG inventory provides data on GHG emissions by sources and removals by sinks for a full time series for the period 1991 to 2015. The gases estimated were carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), oxides of nitrogen (NO_x), sulphur dioxide (SO_2), non-methane volatile organic compounds (NMVOCs) and the precursor carbon monoxide (CO), using a mix of Tiers 1 and 2. The IPCC 2006 Guidelines and software were used for compiling these inventories.

ES 2.1.2 Institutional arrangements and inventory preparation

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 QA and capacity building to meet the enhanced transparency and higher standards of reporting, due to lack of financial resources to maintain permanent staff for a full institutionalization of the process.

The Climate Change Unit (CCU) of the Ministry of Environment and Tourism monitored and coordinated the production of the GHG inventories. Capacity building of the inventory working group members continued. The detailed institutional arrangements adopted for the compilation of the inventory and reporting are provided in the inventory chapter of this report.

ES 2.1.3 Key Category Analysis

Key Category Analysis (KCA) gives the characteristics of the emission sources and sinks which contribute 95% of the total annual emissions.

There are four key categories in the quantitative level assessment when including FOLU for the year 2015, and when excluding FOLU, there is a sharp increase from four to fifteen. This is because the FOLU categories were the highest sinks and emitters, contributing to 91.3 % at absolute level in the KCA.

The results change quite drastically when considering the trend assessment covering the period 1991 to 2015. There are now twelve and eleven key categories when considering the assessment with and without FOLU, with four categories contributing less than 2% of national emissions under both situations.

ES 2.1.4 Methodological issues

All the methods and tools recommended by IPCC for the computation of emissions in an inventory have been adopted in order to be in line with Good Practices. As the IPCC 2006 Guidelines do not fully address compilations at the Tier 2 level, national emission factors and stock factors as appropriate have been derived and adopted to compile estimates at the Tier 2 level partially for the Livestock and Land sectors. The 2006 IPCC Guidelines were supplemented with the European Monitoring and Evaluation Program/European Environment Agency EMEP/EEA Guidebook.

Based on decision 17/CP.8, the Global Warming Potentials (GWP) adopted were those from the IPCC Second Assessment Report for the three direct GHGs, CO_2, CH_4 and N_2O as well as for the gases used for Refrigeration and Air Conditioning.

Default Emission Factors (EFs) were assessed for their appropriateness prior to adoption while country specific EFs and stock factors derived using national data and the IPCC equations were used for Tier 2.

Country-specific Activity Data (AD) are readily available as a fairly good statistical system exists since 2003. 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. Data gaps were filled through personal contacts with the stakeholders and/or from results of surveys, scientific studies and by statistical modelling

ES 2.1.5 Quality Assurance and Quality Control (QA/QC)

QC and QA procedures, as defined in the *2006 IPCC Guidelines (IPCC, 2006)* have been implemented during the preparation of the inventory. Even if QA/QC procedures have been followed throughout the inventory process by the inventory compilers and the QA Officer, a QA/QC plan has yet to be developed to fit within the domestic Measure, Report and Verify system under development. Namibia requested the UNFCCC and Global Support Programme to undertake a QA exercise on its inventory compilation process adopted for the BUR3. Most of the recommendations were addressed during this inventory compilation and the remaining ones included for action in the National Inventory Improvement Plan (NIIP).

ES 2.1.6 Uncertainty assessment

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. The uncertainty analysis has been performed using the tool available within the IPCC 2006 Software. Uncertainty levels for the individual years of the period 1991 to 2015 varied from 26.7% to 29.1% while the trend assessment when adding one successive year on the base year 1991 for the years 1991 to 2015 ranged from 35.8% to 45.8%.

ES 2.1.7 Assessment of completeness

An assessment of the completeness of the inventory was made for individual activity areas and the results are provided in the national and sectoral reporting tables of the inventory chapter. Completeness is almost total.

ES 2.1.8 Recalculations

Original estimates of 1994, 2000 and 2010 were made according to IPCC 1996 Revised Guidelines, Tier 1, lower coverage of activity areas compared to present inventory and default EFs while recalculated values are compiled in line with 2006 IPCC Guidelines, mix of Tiers 1 and 2, the latter for most key categories and an improved coverage.

ES 2.1.9 Time series consistency

This inventory now covers the period 1991 to 2015 and AD for all source categories were abstracted from the same sources. 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.

ES 2.1.10 National inventory improvement plan (NIIP)

The improvements retained can be viewed in the inventory chapter. They are quite numerous and will be attended to as per availability of resources during future inventory cycles.

ES 2.2 RESULTS

ES 2.2.1 Trends in Greenhouse Gases for the period 1991 to 2015

Namibia remained a net greenhouse gas (GHG) sink over the period 1991 to 2015 as the Land category removals exceeded emissions from the other categories. The net removal of CO_2 increased by 25,258 Gg from 75,239 Gg to 100,497 Gg in 2015, representing an increase of 33.6% over these 25 years. During the same period, the country recorded an increase of 6.2% in emissions, from 19,849 Gg CO_2-eq to 21,554 Gg CO_2-eq. The trend for the period 1991 to 2015 indicates that the total removals from the Land category increased from 95,088 Gg CO_2-eq in 1991 to 121,575 Gg CO_2-eq in 2015 (Figure 3.3).

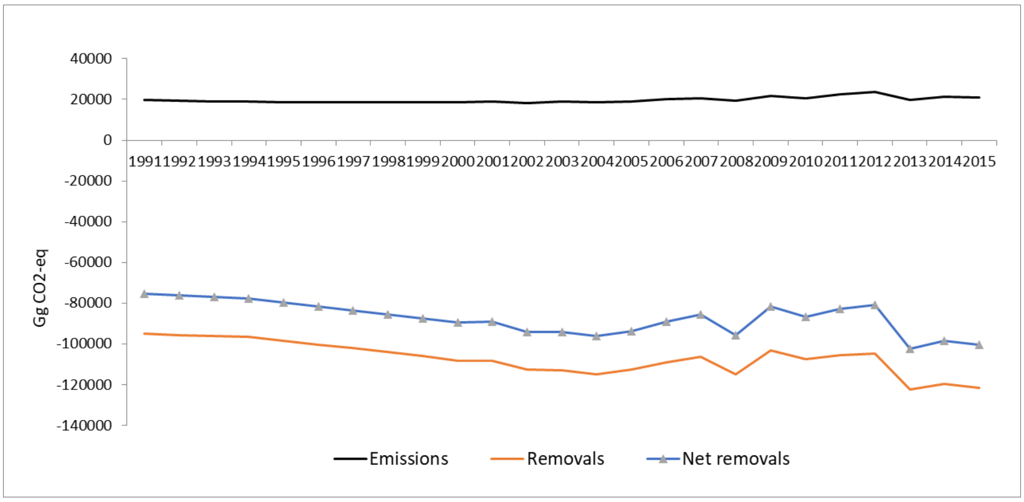


Figure EXSUM 1 - Evolution of national emissions, national removals and the overall (net) situation (Gg CO_2-eq), (1991 – 2015)

Per capita emissions of GHG decreased gradually from 13.3 tonnes CO_2-eq in 1991 to reach 9.9 tonnes in 2002; it then plateaued between 9.8 and 10.0 tonnes up to 2005 after which period it again decreased to 9.5 tonnes CO_2-eq in 2015. The GDP emission index decreased almost steadily from 100 in the year 1991 to 44 in 2015

ES 2.2.2 Trend of emissions by sector

Total national emissions increased by 6.2% over these 25 years. 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 2003. Emissions from the AFOLU sector decreased from 18,574 Gg CO_2-eq in 1991 to 16,856 in 2015, representing a decrease of 9% from the 1991 level. The share of GHG emissions from the AFOLU sector out of total national emissions regressed from 93.5% in 1991 to 80.0% in 2015.

Energy emissions increased from 1,177 Gg CO_2-eq (6.0%) of national emissions in 1991 to 3,541 Gg CO_2-eq (16.8%) in 2015 as depicted in Table 3.8. During the period 1991 to 2015, emissions the increased by three times.

The contribution of the IPPU sector in total national emissions increased from 21 Gg CO_2-eq in 1991 to 518 Gg CO_2-eq in 2015 (Table 3.8). 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 varied slightly over this period with the tendency being for a slight increase over time. Emissions from the waste sector increased from the 1991 level of 76 Gg CO_2-eq to 163 Gg CO_2-eq in 2015, representing a 115% increase.

In 2015, Energy contributed 16.8% of emissions, IPPU 2.5%, AFOLU 80.0% and Waste 0.8%.

ES 2.2.3 Trend in emissions of direct GHGs

The share of emissions by gas did not change during the period 1991 to 2015. 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. In 2015, the share of the GHG emissions was 65.1% CO_2, 22.7% CH_4 and 12.2% N_2O.

ES 2.2.4 Trends for indirect GHGs and SO_2

Emissions of indirect GHGs (CO, NO_x and NMVOC) and SO_2, have also been estimated Emissions of NO_x decreased from 50.5 Gg in the year 1991 to 38.2 Gg in 2015. Carbon monoxide emissions also regressed from 2,547 Gg in 1994 to 939 Gg in 2015. Emissions of NMVOCs increased from 16.0 Gg in 1991 to 24.7 Gg in 2015 whilst emissions of SO_2 varied between 1.9 Gg and 4.2 Gg during the same period.

ES 3. Vulnerability and adaptation

ES 3.1 Introduction

The Vulnerability and Adaptation assessment (NC4-V&A) have two primary focus areas, the sector and constituency levels. The first was to review and prioritize the most significant climate change risks, vulnerabilities, and adaptation for the sectors agriculture, water resources, tourism, health, coastal zones, human settlements, ecosystems and biodiversity. The second was an in-depth analysis of the vulnerability and adaptation of human settlements (constituencies) in Namibia to climate change impacts.

ES 3.2 . Current climate and projected changes

ES 3.2.1 Baseline precipitation and temperature (1981-2018)

The data used to generate the baseline climate, temperature and precipitation, were the medium-term records (1981-2018) of temperature and precipitation, which were statistically downscaled from an ensemble of 35 GCMs (General Circulation Models) by the Climatic Research Unit (CRU) of the University of East Anglia. Mean annual rainfall ranged between 25 mm to just above 600 mm (Figure 4.1), largely because of its proximity to the northward-flowing Benguela current, which brings cold water to its western shores. The average maximum temperature during the hottest months (September to February) is usually above 30°C, except for the much cooler coastal areas. July is the coolest month over much of the country, with average minimums of less than 10°C.

ES 3.2.2 Historical Climate Trends (1901-2016)

The average annual temperature has been increasing at a rate of 0.0123°C annually over the period 1901-2016. Detecting trends in precipitation is typically more difficult than in temperature for countries with highly variable arid climates such as Namibia. This is because a single extreme rainfall event can contribute a significant proportion of the annual rainfall in some regions. Unlike temperature, there are no obvious trends in precipitation during the reference period, namely a non-significant increase of about 0.039 mm per year.

ES 3.2.3 Climate Projections: Mid-century (2040-2069) and End-century (2070-2099)

The projections presented below are averages of statistically downscaled projections made by 35 GCMs.

Temperature

It is predicted with a high degree of certainty that Namibia can expect an increase in temperature at all localities, with the highest increase in the interior. The north-eastern parts of the country are expected to experience the highest increases in average annual temperature for both time horizons. It is projected that the mean annual temperature will increase by 2°C and 4°C relative to the baseline (1981-2018) by mid-century and end-century respectively, under the worst-case scenario.

Precipitation

There is greater uncertainty associated with the projection of precipitation compared to temperature. As a result of this, there is little agreement among the 35 GCMs on whether precipitation will decrease, remain the same or increase. However, the majority of the 35 GCMs predict that Namibia will become drier, that rainfall variability will likely increase, and that extreme events such as droughts and floods are likely to become more frequent and intense. With regards to precipitation, mid-century, and end-century projections respectively show, with low confidence, a 7% and 14%, reduction from the baseline period (1981-2018).

ES 3.3 Vulnerability, adaptation and impact analysis

ES 3.3.1 Current Drivers of Climate Change Vulnerability

The country's vulnerability stems from its climate, landscapes, socioeconomic and environmental characteristics (i.e., its geography). For instance, the country's geographic position on the continent and sub-continent makes it susceptible to erratic, variable, and unreliable rainfall.

Agriculture

Agriculture is a key sector of the Namibian economy. It is not only the largest employer, accounting for about 13% to the labour force, but also critical to livelihoods and food security. Over two-thirds of households practice subsistence cropping and pastoralism, mostly on communally-held lands. Less than 10% of the land surface is used for crop production, while nearly 75% is used for livestock production.

Agricultural output is extremely sensitive to climatic conditions. Periodic droughts cause considerable stock losses and reduce grain production. The agriculture sector is impacted directly by changes in precipitation, temperature, and evaporation, and through secondary impacts, including disaster risk and health issues.

Climate change problems are superimposed upon the many other challenges and stressors that the agriculture sector already faces, such as environmental degradation, disease outbreaks, and higher input costs. Current/potential adaptation options and challenges are:

- Adaptation strategies include the implementation of Climate Smart Agriculture, improved water management, improved monitoring and early warning, the development of knowledge and decision-support systems, and the development of new crop varieties and technologies;
- Data gaps include the implications of higher temperatures on livestock health; changes in the pest, weed and disease distribution; biophysical response of crops to elevated temperatures and levels of CO_2;
- Barriers to adaptation include reduced extension service and a slow uptake of Climate Smart Agriculture and Conservation Agriculture techniques;
- Possible benefits of climate change include higher crop yield in those areas with increased precipitation and elevated levels of CO_2; and societal benefits of implementing conservation agriculture and efficient irrigation methods.

Coastal Zones

The Namibian coastline, on the Atlantic Ocean, is approximately 1500 km long and consists of 78% sandy beaches, 16% rocky shores and 4% mixed sand and rocky shores. Lagoons back only 2% of the shore. Tide gauge records from Lüderitz and other localities on the west coast of southern Africa over the last 30 years have revealed an estimated sea-level rise that is comparable with the global measurements (IPCC, 2014). The Fifth Assessment Report (AR5) shows that, under the a2 greenhouse gas emissions scenario, global sea-level rise is estimated to be above those recorded in the mid-1990s (that is, baseline) by 6 - 25 cm by 2030; 10 - 65 cm by 2070; and 23 - 96 cm by 2100 (IPCC, 2015).

The most significant drivers of climate change risks and vulnerability that are of importance to coastal environments and fisheries are: modification of terrestrial climatic and hydrologic processes; changes in coastal and oceanic circulation processes; ocean acidification; increased sea surface temperature (SST); sea-level rise (SLR); increase in sea storminess; and changing wind systems.

The adaptation measures proposed for coastal zones can be classified broadly into "*no regrets*" and "*additional*" options that are proactively designed to counter sea-level rise. The *no regrets* options available to Namibia include: enforcement of development restrictions within the coastal buffer zone; reduce the degradation of wetlands, estuaries, dune cordons and sandbars; integration of sea-level rise scenarios into future planning decisions; incorporate sea-level rise risks in disaster management strategies; and alleviate poverty and improve living conditions.

Additional options are new interventions or investment, additional to the business as usual and existing efforts, designed to improve wellbeing, maintain the environment, and ultimately counter sea-level rise. These options can be classified into physical, biological and institutional responses. Physical options are hard engineering techniques such as seawalls, groynes, detached breakwaters, and revetments. Biological options are more natural, less likely to produce adverse consequences and more cost-effective than most physical options. They include dune cordons, estuary and wetland rehabilitation, and kelp beds. Institutional options are policy or decision-making responses and include vulnerability mapping and risk communication, design and implementation of appropriate and effective legislation, establishment of early warning systems, research and monitoring and design of appropriate insurance products to address sea-level rise.

Water Resources

Namibia relies on dams, ephemeral rivers and aquifers for its water supply. These water resources are supplemented to a limited extent by unconventional sources such as reclaimed water and desalination. The absence of perennial rivers in Namibia's interior means that the country is reliant on rainfall as its natural water source. The semi-arid climate over most of the country coupled with high evaporation rates make the country one with a net water deficit (mean annual rainfall minus potential evaporation), ranging from -4000 mm in the southeast to -1600 mm in the northeast.

The drivers of climate risks and vulnerabilities in the water sector are well known, namely:

- Escalating financial/economic costs of supplying adequate water to agriculture (mainly crop irrigation), mining/industry, commerce, and an expanding, urbanizing population;
- Increasing concentrations of pollution which threaten the quality of diminishing water supplies;
- Increasing water scarcity and competition with neighbouring countries for available water;
- Environmental damage resulting from the unsustainable removal of water from underground aquifers;
- Increasing water demand and water pollution by irrigation schemes; and
- An increase in transboundary issues with upstream users and downstream users that share Namibia's perennial rivers.

To ensure sustainable long-term access to water, and effectively manage and conserve the country's water resources with the uncertainty of climate change, the following adaptation options are relevant:

- Promote efficient water harvesting techniques in areas that will benefit from an increase in rainfall;
- Promote the management of inflow and outflow of water;
- Promote the recycling and re-use of water;
- Promote the use of desalination technologies to increase water supply;

- Promote flexibility in water use allocations and increase coverage of water supply and water treatment facilities across sectors, households, and individuals targeting both rural and urban communities at local, regional and national level;
- Promote and encourage integrated water resources management;
- Promote and encourage artificial recharge of groundwater in the arid and semi-arid environment;
- Construct new water facilities, infrastructure and promote alternative water access; and
- Prevention of water pollution.

Health

Based on the 2016/17 Namibia Intercensal Demographic Survey and the 2006/07 National Demographic and Health survey, the main causes of deaths in children under five years are diarrhoea (42%), under-nutrition (40%), malaria (32%) and acute respiratory infections (30%), although it must be noted that multiple causes of death are frequent. All these causes of death have a strong environmental component linked to climate.

Climate change is already compounding the causes of infant and adult mortality and this will exacerbate with climate change in the future. The following are the observed/projected climate change risk and vulnerabilities in the Health sector:

- Higher rainfall in areas that were previously not used to receive these amounts will increase populations of disease-carrying insects in these areas;
- Furthermore, flood incidences, whose frequency is increasing, are usually accompanied by outbreaks of water-borne diseases and infections, such as cholera and diarrhoea;
- Higher temperatures are likely to increase mortality among the elderly, infants and others whose health is already poor, and also increase the incidences of disease epidemics that are linked to high temperature; and
- Drought decreases the nutritional status and the availability of clean water. Reduced safe water provision and secure nutrition, would increase the rate of respiratory and gastrointestinal infections and other water-borne diseases.

Adaptation needs and barriers in the Namibian health sector include:

- A lack of understanding of the linkages between climate and health in Namibia. A quantitative vulnerability and risk assessment for the health sector should be performed to identify the most important health risks and most vulnerable populations or communities;
- The ability of the health care system to respond to climate change-induced health problems is or will be constrained by the sparse population distribution in Namibia because the planning for health care infrastructure and staffing is problematic;
- Large distances impede the accessibility and effectiveness of health care infrastructure since the maintenance of infrastructure, coordination of the state ambulance service, and specialist referrals are often challenging; and
- There is a lack of formal and supported inter-sectoral linkages between health and the environment, which increases the vulnerability of the sector to climate change.

ES 3.4 Vulnerability of human settlements

About 22% of Namibia's territory is desert, 70% is arid to semi-arid, and the remaining 8% is dry sub-humid. Namibia's semi-arid-to-arid landscape, where most of the population live, experiences variable and sometimes extreme climates, adverse environmental change, and a relative scarcity of and decline in natural resources such as water, arable land, rangeland. Historically, the Namibian population has adopted several coping mechanisms. However, despite their adaptation efforts, many communities in Namibia exhibit low levels of adaptive capacity due to challenges such as marginalization, underdevelopment, poverty, inequality, maladaptive policies, and increasing population growth. The existing levels of vulnerability of communities in Namibia are likely to intensify with climate change in the future. The goal is to identify constituencies (that is, the unit that is used to analyse the vulnerability of human settlements) that are relatively more vulnerable to climate change impacts. This is done to make adaptation planning spatially explicit, thus ensuring that the focus is emphasized on constituencies mostly in need of resilience building by using an index-based approach in the assessment of the vulnerability of constituencies. The index-based approach is conceptually and theoretically framed within the context of the IPCC definition of vulnerability, that is vulnerability is a function of impact (exposure and sensitivity) and adaptive capacity.

ES 3.4.1 The Exposure of Constituencies

Exposure measures the climate-related attributes of constituencies, that is the *character, magnitude, and rate of change* and *variation* in the climate. Exposure variables adopted were variance in temperature, precipitation, and water balance during the period 1901-2018, and the probability of flood and drought events during the period 1949-2018.

These factors are then combined to give a single index and summed up at the constituency level to create an *exposure index*. The larger the value of the index, the higher the exposure. For presentation purposes, constituencies were classified into five categories, Very High, High, Medium, Low or Very Low exposure to climate change risks/threats. Out of the 122 constituencies, temperature was found to be the highest contributor to climate risks (50 constituencies) followed by drought (39).

ES 3.4.2 The Sensitivity of Constituencies

The second stage of the vulnerability assessment framework involved the measurement of the sensitivity of constituencies to climate change exposure. Sensitivity measures the *degree to which a system is adversely or beneficially affected by climate-related risk factors*. The sensitivity index was computed by summing up all the values of the standardized variables in the sensitivity domain at the constituency level. Like the exposure index, a larger value indicates high sensitivity, whereas a lower value indicates low sensitivity.

Based on the computed *sensitivity indices*, constituencies in the southern part of the country were found to be more resilient as opposed to the northern regions. Food insecurity, child-headed households, and vulnerable livelihoods were found to be the key drivers of sensitivity.

ES 3.4.3 The Adaptive Capacity of Constituencies

The third stage of the assessment framework consist in measuring the adaptive capacity of constituencies. That is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Furthermore, the study conceptualized adaptive capacity using the concept of Multiple Deprivation which is a measure of the level of unmet needs in terms of material, education, employment, health, housing, and services in each constituency. The spatial patterns and distribution of deprivations are not random, but outcomes of ineffective social, political, and institutional processes.

The study empirically computed the *adaptive capacity index* by summing, at the constituency level, the values of all the standardized variables under the adaptive capacity domain. A larger *adaptive capacity index* value indicates *high deprivation*, which in turn implies low *adaptive capacity*, whereas a smaller *adaptive capacity index* value indicates *low deprivation*, which means *high adaptive capacity*. Health deprivation, material deprivation, and service deprivation were found to be the key drivers of the adaptive capacity of constituencies in Namibia. Generally, there is a trend with constituencies in the South and Centre having a high adaptive capacity as opposed to the Northern areas.

ES 3.4.4 The Vulnerability of Constituencies

Under the IPCC framework, vulnerability is measured as a function of the exposure, sensitivity, and adaptive capacity attributes of a constituency. The vulnerability index (that is, NCCVI, Namibia Climate Change Vulnerability Index) is computed using the Principal Component Analysis (PCA). Larger NCCVI values indicate higher vulnerability, whereas smaller NCCVI values indicate low vulnerability.

The NCCVI scores for most of the constituencies in the Omusati, Kavango (East and West) and Zambezi regions are high, implying that these constituencies are relatively highly vulnerable to the impacts of climate change. The majority of the constituencies in the Karas, Hardap, and Erongo regions have low NCCVI scores, implying low vulnerability to climate change risk.

ES 3.5 Climate change adaptation

The Vulnerability and Adaptation assessment should drive action plans within a well-defined framework. The latter should serve to implement and track actions for reporting to the UNFCCC. Successful implementation can only be possible when barriers and constraints are removed.

ES 3.5.1 Climate Change Adaptation Actions

Current Adaptation Priorities: Namibia's current adaptation are identified in the National Policy on Climate Change (NPCC) and National Climate Change Strategy and Action Plan (NCCSAP); Republic of Namibia, 2015. These priorities are aligned with those sectors identified as being particularly vulnerable to climate change. A total of 32 programmes and projects were identified. Most of the current climate change adaptation projects, and programs in Namibia are directed in the areas of agriculture, fisheries, sustainable land management, government, climate information and research, ecosystems and biodiversity, forestry and energy. The projects tend to focus on capacity building, knowledge communication, field implementation, and policy formation and integration, with all nationally implemented projects supporting community-based adaptation.

Alignment of Current Adaptation Activities with NCCSAP

The current adaptation projects and programs were analysed further to assess their coverage in terms of the Adaptation Agenda of the NCCSAP (that is, Agenda A, which focuses on climate change adaptation strategic themes and aims). Agenda A of the NCCSAP has four themes, namely, Food Security and Sustainable Resources (A1), Sustainable Water Resources (A2), Human Health (A3) and Infrastructure (A4).

Out of the 32 identified projects and programs, 22 programs and projects primarily focussed on adaptation while the others had either a research focus or were multi-sectoral/cross-cutting. Of the 22 programs and projects, 20 were aligned to Food Security and Sustainable Resources, while the remaining two were aligned to Sustainable Water Resources. None of the projects and programs directly addressed climate change adaptation issues on Human Health and Infrastructure. Therefore, human health and infrastructure are not receiving targeted attention within the current programme.

Approach for New Adaptation Initiatives

Since climate change adaptation initiatives are evolving from a sectoral approach to assume a community-based and settlements approach following the definition of settlements by IPCC, therefore:

- It is becoming imperative to consider youth, women-headed households, and vulnerable groups in the adaptation strategies to enhance relevance and commercial viability of community-based initiatives, e.g. agribusiness.

- Climate change adaptation investments at community-level can target the climate change vulnerable hotspots, as identified using the NCCVI results coupled with the characteristics of human activities for livelihoods and resource sustainability; and
- Adaptation assessments should seek to improve the identification of climate change and climate variability hazards and risks and match these with replicable and scalable successful and innovative adaptation strategies.

ES 3.5.2 Conclusion and Recommendations

Climate change adaptation has been project-based for the past ten years and coordinated from a small secretariat in the DEA, MET. It is difficult to measure progress made in respect of climate change adaptation (CCA) without baselines as reference points for inference of success of the implemented actions and activities. This warrants a further strengthening of the CCA planning framework for enhanced coordination and implementation. Mainstreaming of CCA in sector policies, plans, and programs and decentralized at sub-national levels requires a concerted effort if Namibia's economy is to become climate resilient by 2030. Financial barriers limit the effectiveness of the CCA actions country-wide and the provision of extension services in rural areas to increase the agricultural capacity of communities. Financing of CCA actions are project-based and funded by international development partners without a coordinated and consistent system to follow-on quantitatively. Efforts have been recently made to include climate change issues in the national development planning framework to measure progress on the results of the investments.

The climate change resource center and centralized database is not yet established for the coordination of climate change observation systems. The latter is particularly needed if meteorological data are to be processed for the establishment of an early warning system for preparedness during extreme events such as drought country-wide, and flooding in the north-central regions and the north-eastern floodplains. Data management for the crop sub-sector and CBNRM activities in conservancies and community forests are updated regularly.

Ecosystem changes have not been monitored regularly, but the review of the National Core Environmental Indicators in 2015 developed through the Environmental Monitoring and Indicators Network (EMIN) and used in the first Integrated State of Environment Report in 2006 will provide impetus to regular monitoring and evaluate ecosystem changes. The Benguela Current Commission (BCC) has produced the second State of the Marine Environment in 2014. The use of the ecosystem-based approach in fisheries management with its modules on environment, social, governance, and ecosystem health will improve the State of the Marine Environment reporting. The National Core set of Environmental Indicators was adapted for the coastal zone in 2015 based on the Pressure-State-Response (PSR) Framework developed by OECD. Climate change features in this indicator framework, albeit without sufficient depth. Climate change and their impacts ought to be monitored based on a baseline of ecological, social, economic and governmental conditions supported by a good indicator framework.

ES 4. Mitigation

ES 4.1 Introduction

Non-Annex I country, initially had no obligation to reduce their GHG emissions as signatory Parties to the Convention. Given the dire situation, namely the continued increase in GHG emissions in the atmosphere and IPCC projections for the global warming to exceed the 2 ^{o}C level by 2050, decisions 1/CP.19 and 1/CP.20 were adopted by the Conference of the Parties, the goal being to limit warming to less than 1.5^{o}C. In conformity with these decisions, the Republic of Namibia prepared and submitted its Intended Nationally Determined Contributions (INDC) to the United Nations Framework Convention on Climate

Change. Furthermore, the Government of Namibia has reviewed and updated various policies and strategies to change its development agenda into a green low carbon economic pathway within the framework of the SGs. Namibia has embarked on various projects and activities aiming at curbing GHG emissions and increasing its sink capacity. This mitigation analysis updates the previous one presented in the NC3 by addressing options which present the highest potential for mitigation based on the latest emissions estimates, with base year 2010 up to the 2035-time horizon.

ES 4.2 Assessment method

The major principles guiding this mitigation assessment rest on the International, regional and national contexts. The drivers are the Paris Agreement, the insecurity linked with ESKOM's capability to supply electricity to the country, the need to generate electricity from indigenous sources with a target for the share of renewables in the national mix of energy sources and the transboundary agreement with Angola on the use of water from the river XXXX. Additionally, the socio-economic development of the different economic engines, population growth and urbanization rate are other factors considered in the assessment.

A Business as usual (BAU) scenario has been developed for all categories and sub-categories based on the situation in 2010, the base year for this assessment. Assessment of their mitigation potential was done by comparing emissions or removals of the different measures identified within the category or sub-category to the BAU scenario. The difference between the BAU and mitigation scenarios emissions or removals of the category under assessment gives the emission abatement or sink enhancement value of the potential measure. If several measures can contribute to mitigation in a single category, their values were added to provide for the full mitigation potential of that category. The emissions and removals from all categories were then summed to give the abatement potential at the different time steps under consideration for the sectors and finally at the national level. Since the well-developed and agreed strategies within current development plans are to the 2030 time horizon, this mitigation analysis covers the period up to the year 2035.

ES 4.3 Scope of the assessment

Due to time constraints, the exercise was limited to categories offering the highest mitigation potential based on the KCA, and to measures offering a high success rate for implementation. The electricity generation, road transportation and LAND categories were prioritised for the assessment. Due to its importance in relation to health and sustainable development, the waste sector also has also been considered.

ES 4.4 Socio-economic scenarios

For this exercise, the population projections from the National Integrated Resource Plan (NIRP) has been preferred for adoption because all electricity demands have been based on them and also since this activity area is highly influential on other issues such as use of biomass for residential purposes. The adoption of this population projections ensures consistency in the assessment. The NIRP worked on a low, medium and high variant for projecting the population. Throughout the study, the medium variant has been adopted. The population stood at 2.077 million in 2010 to increase by about 1.9% up to the year 2015. Thereafter the rate of increase adopted is 1.8% to 2027, 1.7 to 2033 and 1.6% to 2035. Based on these growth rates, the population is projected to be 2.505 million in 2020, 2.733 million in 2025, 2.962 million in 2030 and 3.185 million in 2035.

Between 1991 and 2011, the increase in urban population largely outpaced the rural component of the total population. A medium-term profile (annual projections until 2035) for urbanization was developed based on past recorded trends, initial projections as set out in Vision 2030 and NSA population projections of 2011. The main features are an urbanization rate of 1% year on year for the period 2010 to 2030 and thereafter by 0.75% up to the year 2035. Thus, by 2030 the urban population is projected to be 62% of the total population, bringing the number of persons living in towns to 1.836 million. In case the projected urbanization level reaches 65.8% in 2035, this fraction of the population will stand at 2.094 million.

ES 4.5 National mitigation potential

Emissions stemming from the BAU scenarios for the base year 2010 and the projections for 2025, 2030 and 2035 are given in Table 5.1. Relative to the year 2010, the country will increase its sink capacity by the year 2025 after which it will regress. The sink capacity is projected to increase from -83,999 in 2010 to -94,448 in 2025 and decrease to -87,039 in 2030 and -76,015 in 2035. The AFOLU sector is the driver of this situation with the sectors Energy, IPPU and Waste being emitters. Emissions increases for these three sectors over the study period.

Different measures have been evaluated for the Energy, AFOLU and Waste sectors as detailed further. For summing up to obtain the national mitigation values at the different time horizons, the best scenarios were chosen. The abatement potential (Gg CO_2-eq) at the national level, when compared with the BAU scenario, and the contribution from the different sectors evaluated are presented in Table 5.2EXSUM 1.

Table EXSUM 1 - Mitigation potential (Gg CO2-eq) for the years 2025, 2030 and 2035

Year	Energy	IPPU	AFOLU	Waste	Total
2025	3,665.2	43.8	-28.5	123.1	3,803.6
2030	5,612.6	112.8	4,254.3	164.3	10,144.0
2035	7,111.0	169.8	13,395.0	212.8	20,888.6

When evaluating the final potential contribution at the national level, it depends on whether the country is a sink or emitter as this may change the perspective and understanding. Hence, both alternatives are presented. Expressed relative to the net national sink capacity, the mitigation potential represents 4, 12 and 27 % of the sink capacity under the BAU scenario of the respective year under assessment. That is under the mitigation situation, the sink capacity increases by these levels. When viewed with respect to total national emissions, the mitigation potential is 8, 24 and 39% for the years 2025, 2030 and 2035. That is, under the mitigation situation, this represent the level of reduction in emissions. In fact, these are the potential mitigation contribution of the country for the three time steps for the options assessed.

ES 4.6 Energy sector mitigation assessment

ES 4.6.1 Energy Industries - Electricity generation

Namibia electricity generation is dominated by imports from the SAPP, with the major share supplied by ESKOM of South Africa. In fact, in the base year 2010, Namibia imported 67% of its electricity and generated the remaining 33% for a demand of 3,767 GWh. By 2015, the share of imported electricity was at 65%.

The Namibian energy policy to the 2050 horizon (2007) used in economic and demographic projections to chart the roadmap, with focus on the level of engagement of the Namibian Government and the level of cooperation between Namibia, regional and international Governments and organizations, charted the future strategy for the energy sector. Based on the Energy policy, the ECB completed the National Integrated Resource Plan (NIRP) to cover the next 20 years in April 2013. The NIRP was revised in 2016 to suit the national, regional and international contexts. Guiding principles are reduction of emissions in line with the Paris Agreement, difficulties experienced by ESKOM to meet demand in South Africa and export commitments, and the national strategy to generate electricity from indigenous resources. Electricity generation action plan

For the purpose of this assignment, the NIRP 2016 which has been worked out up to the year 2035 has been considered. Out of the 11 generation expansion scenarios of the NIRP (2016) detailed in section 6.3 of the plan, the four with the highest share of renewables in 2035 within the mix of fossil and renewable sources were assessed for their mitigation potential.

ES 4.6.2 Mitigation assessment

Business as Usual scenario

For the BAU scenario, the electricity demand was adopted from the NIRP for the 2020, 2025, 2030 and 2035-time steps but discounting 10% as losses on the grid. The fuel mix of 2010 consisted of 32.7 % hydro, 67% coal, assuming imported electricity is generated with this fuel, and 0.3% fuel oil. The fuel mix of 2010 is used for the forecasted years. The amounts of fuel estimated for the fuel mix was calculated and emissions were then computed using the IPCC 2006 software. CH_4 and N_2O were converted to their CO_2-eq using the same GWPs adopted for the inventory, that is those from the Second Assessment Report of IPCC.

The demand increases from 2010 to 2035, representing increments of 73% to 2025, 106% to 2030 and 145% to 2035. Emissions increased from the base year value of 2,760 Gg CO_2-eq in 2010 to 4,899 in 2025, 5,844 in 2030 and 6,942 in 2035. This drastic increase over time is due to the phasing out of imports of electricity.

Mitigation scenarios

The energy supply-demand balance exercise from the NIRP (2016) for all scenarios was adopted and the amounts of fuel by source calculated. The firm energy supply was considered as being generated from solar PV, wind, biomass and coal with the latter being phased out almost totally when imports ceases in 2024 and most coal plants retired in 2025. Hydro is mainly used to meet the peak demands. Biomass from the invader bush is calculated as being sustainably produced and harvested over time. All imports cease as from 2024 and only renewables are added as from the year 2020 onwards till 2035.

All scenarios were assessed for their fuel mix over the different time steps to meet the national demand forecasted and the 4 scenarios having the highest share of renewables in 2035 were selected for evaluating their mitigation potential compared to the BAU scenario. They are scenarios 4, 5, 8 and 10 of the NRP (2016). The share of the different energy sources is presented in Figure 5.3 2 for the 4 mitigation and BAU scenarios.

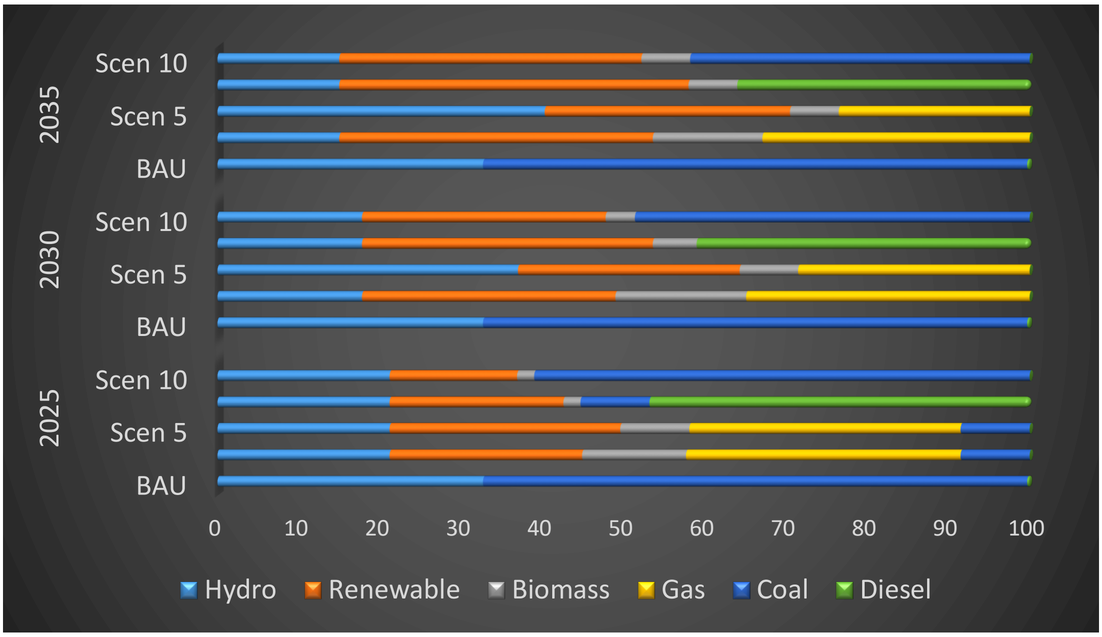


Figure EXSUM 2 - Share of different energy sources for the years 2025, 2030, 2035 and BAU scenarios

Emission estimates under the BAU and mitigation scenarios

The fuel amounts derived from the electricity demand of the various scenarios and BAU were fed in the IPCC 2006 software to compute emissions. The difference in emissions between the BAU and each individual mitigation scenario provides its abatement potential. This exercise has been performed for the 2025, 2030 and 2035-time horizons and compared to the BAU scenario with 2010 as base year.

Under the BAU scenario, the emissions will stand at 4899 Gg CO_2-eq in 2025, 5844 Gg CO_2-eq in 2030 and as high as 6942 Gg CO_2-eq in 2035. The mitigation scenarios assessed emitted in between 1523 to 4450 Gg CO_2-eq in 2025, 919 to 4240 Gg CO_2-eq in 2030 and 902 to 4339 Gg CO_2-eq in 2035.

These emissions represent a varying range of abatement potential as per the energy mixes used in the different scenarios. Scenarios 4 and 5 offer the highest mitigation potential for all time steps. The reduction in the emissions for scenarios 4 and 5 amounted to 3,356 and 3376 Gg CO_2-eq in 2025, increasing to 4,699 and 4,925 Gg CO_2-eq in 2030 to reach 5665 and 6040 in 2035 as the level of renewables increases in the fuel mix of these scenarios. For the same time steps, scenario 8 showed an intermediate mitigation potential with 2,244 Gg CO_2-eq in 2025, 3,708 Gg CO_2-eq in 2030 and 4,709 Gg CO_2-eq in 2035. The worst case, scenario 10 offers a potential reduction of only 449, 1,604 and 2,603 Gg CO_2-eq in 2025, 2,030 and 2,035 respectively.

Compared to the BAU scenario, the magnitude of the mitigation potential varied from 9 to 69% in 2025, 27 to 84% in 2030 and 37 to 87% in 2035. These ranges corresponded with renewables contributing respectively between 39 to 58% in 2025, 51 to 71% in 2030 and 58 to 76% in 2035.

ES 4.6.3 Road transport mitigation assessment

Description of sector

Road transportation is the dominant mode of Namibia's transport system for both passengers and goods. In 2010, there was a total of 249,421 vehicles, all classes confounded. This fleet increased by 95,572 vehicles between 2000 and 2010 indicating an average growth of about 5% annually. This trend has been maintained to project the number of vehicles up to the year 2020 for the BAU scenario. The fleet is then projected to increase by 3% annually to 436,893 vehicles from the year2020 to 2025, by 2.6% annually till 2030 to reach 493,940 vehicles and by 2.6% each year up to 2035 to 550,987 vehicles.

The transport sector consumes more energy than any other productive sector of the Namibian economy. Liquid petroleum products for transport constituted over 70% of Namibia's total energy demand. This is somewhat distorted and is explained by the fact that Namibia uses only minimal amounts of fossil fuels in electricity production as it imports that commodity.

The Business as usual Scenario

Between 2010 and 2025, the vehicle population is expected to increase by 75%. This increase will be of the order of 98% in 2030 and 121% in 2035 compared to the base year (2010) when the vehicle population stood at 249,421 vehicles. The fleet of light passenger vehicles and light load vehicles will constitute 88% of the total number of registered vehicles based on the projections.

Based on the above assumptions, it is projected that fuel consumption in the road transport sector under the BAU scenario will increase more rapidly for diesel as opposed to gasoline as the ratio of vehicles running on these fuels changes in the future. Thus, based on the year 2010, gasoline is projected to increase by 18% in 2025, a further 7% in 2030 and another 5% by 2035. Diesel consumption is expected to shoot up in 2025 by 165% of the amount used in 2010, 209% in 2030 and 255% by 2035.

In the absence of any mitigation action, the consumption trend represents aggregate emissions of 2,223 Gg CO2-eq in the base year 2010 and projected to increase to 4,322 Gg CO2-eq in 2025, 4,912 Gg CO2-eq in 2030 and 5,508 Gg CO2-eq in 2035 respectively. These will represent increases of the order of 94%, 121% and 148% for these three time steps over emissions of the base year 2010. The road transport sector emissions will represent 44% of national emissions of the energy sector in 2025, 43% in 2030 and 42% in 2035.

Aggregated emissions for the BAU scenario for CO_2 and NOx, equated with N2O, from the SUTMP project is forecasted at 480 Gg CO_2 eq in 2035. These latter figures are retained for calculating the emissions reduction under the mitigation scenario.

Mitigation Options

Previous reports (Energy Policy Scenarios for Namibia 2007-2050) on energy needs in Namibia confirmed that due to its greater flexibility, road transport will continue to influence the socio-economic development of the country. However, given the more recent changes and commitments of Namibia within the international context relative to the COP decisions and the SDGs, there is need to review this policy.

Choice of Mitigation Option

From this list of potential mitigation measures, only the most prominent ones that were deemed most applicable were further analyzed. These are:

- The introduction of new generation diesel or CNG propelled buses having EURO 3 or 4 emission standards with the objective of reducing the demand for light passenger vehicles by at least 30%;
- Conversion of 25% light load vehicles and light passenger vehicles into dual fuel vehicles using LPG and gasoline; and
- Encouraging pooling and bulk loading in internal transport of goods with incentives to increase registration of ≤15 tons GVM goods vehicles by up to 30% in 2035, thus causing a reduction in the forecast fleet of light load vehicles.

Out of these measures, the first option has been implemented within the framework of the SUTMP, the second one has not taken off due difficulties in developing a reliable supply system while the third option is difficult to evaluate within this assessment.

The SUTMP is a much wider study, incorporating other issues in addition to road transportation. For example, walking and cycling that are not recognized modes of travel due to lack of proper infrastructure and commuter trains are introduced in the master plan as the latter reviews the infrastructure, urbanization model and the transport network. The emissions reduction estimated in the study for the year 2032 has been adopted for the year 2035 in this assessment to keep pace with the delay in implementation. Since the emissions avoided has been computed and presented only for the completed project in the report, this has been adjusted according to the phase that has been implemented and to be completed by the time steps 2025, 2030 and 2035.

Estimation of mitigation potential

The gross mitigation potential in the road transportation sector is projected at 167.8 Gg CO_2 eq in 2025, 560.0 Gg CO_2 eq in 2030 to reach 923.5 Gg CO_2 eq in 2035. Emissions resulting from transport of wood for mitigation in other sectors range from 2.6 to 3.8 Gg CO_2 eq. The net emissions reduction in the road transportation sector after discounting these emissions will amount to 165.2 Gg CO_2 eq in 2025, 556.7 Gg CO_2 eq in 2030 and 919.7 Gg CO_2 eq in 2035.

Residential sector

Over and above electricity, fuels burned in the residential category for various purposes are fuelwood, charcoal, LPG, kerosene and paraffin wax. Fuelwood is the most consumed fuel and even if it is not of fossil origin, it results in emissions of CO2 in the Land sector and CH4 and N2O when burned in the Energy sector.

BAU scenario

Emission estimates for the BAU scenario which stood at 126 Gg CO_2 eq in 2010, peaked at 138 Gg CO_2 eq in 2015, and is forecasted to be at 124.2 Gg CO_2 eq in 2025, 114.1 Gg CO_2 eq in 2030 and 117.8 Gg CO_2 eq in 2035. This reduction in emissions in the BAU scenario over time is due to the shift from fuelwood to other cleaner sources of energy such as electricity and LPG as the population migrates from the rural areas to towns.

Mitigation options

Projected mitigation potentials decrease over time for paraffin wax with the reverse for fuelwood. The potential reduction decreases from 19.2 Gg CO_2 eq in 2025 to nil in 2035 while it increases for fuelwood from 26.0 Gg CO_2 eq in 2025 to 32.6 Gg CO_2 eq in 2035. However, total reductions are projected to decrease from 45.2 Gg CO_2 eq in 2025 to 32.1 Gg CO_2 eq in 2030 followed by a slight increase thereafter to 32.6 Gg CO_2 eq in 2035. This represent reductions of the order of 52.3, 43.8 and 44.2% respectively for the years 2025, 2030 and 2035.

ES 4.7 IPPU sector mitigation assessment

Out of the total emissions from this sector, cement production contributed 52.3%, zinc production 22.4% and RAC 17.9 % to sum up to 92.6%. Hence, only cement production and RAC have been privileged for mitigation action.

ES 4.7.1 BAU scenario

For cement production, an increase of 5% annually has been adopted up to the year 2035 as the production capacity exist and the industry is anticipated to expand. This will lead to emissions of 880 Gg CO_2 eq, 1,037 Gg CO_2 eq and 1,193 Gg CO_2 eq in 2025, 2030 and 2035 respectively.

For RAC, it is assumed that there will be an incremental use of 4% annually for stationary air conditioning and refrigeration up to 2025 and 3% onwards up to 2035. Regarding mobile air-conditioning, the projected number of vehicles adopted for estimating emissions in the road transportation category has been adopted. Based on these assumptions, the emissions are estimated at 158.0 Gg CO_2 eq, 185.7 Gg CO_2 eq and 225.5 Gg CO_2 eq for the time steps 2025, 2030 and 2035 respectively

ES 4.7.2 Mitigation assessment

In the cement industry, the possibility of replacing 10 and 20 % of the clinker entering in the production has been considered. Emissions reductions is projected to vary from 17.62 Gg CO_2 eq (2%) to 59.65 Gg CO_2 eq (5%) for the low scenario and from 35.24 Gg CO_2 eq (4%) to 119.31 Gg CO_2 eq (10%) for the high scenario.

For RAC, two mitigation options are assessed. They are the recovery of the refrigerant from vehicles and refrigerators when they are retired and the replacement of R34a by the new gas R1234yf in vehicles since the latter action has already been implemented in Europe since 2017. It is assumed that other manufacturers will follow, and that all equipment will use R1234yf which has a GWP of 1 as from the year 2025.

Since recovery of refrigerant from used equipment is a new practice, it is assumed to gain momentum with time. Therefore, 5, 10 and 15% of retiring vehicles and refrigerators are targeted with the recovery of the refrigerant. This action is expected to result in a total emission reduction of the order of 4.3 Gg CO_2 eq in 2025, 11.1 Gg CO_2 eq in 2030 and 19.3 Gg CO_2 eq in 2035 from retired vehicles and refrigerators. Reductions of 4.3, 18.7 and 31.2 Gg CO_2 eq are forecasted when new equipment with R1234yf enters the market as from the year 2025 instead of R134a.

The total emissions avoided in RAC amounts to 8.5, 29.9 and 50.5 representing reductions of 5%, 16% and 22% for the year 2025, 2030 and 2035 respectively.

The mitigation assessment based on the assumptions provided is projected to reduce emissions in the IPPU sector by 43.8, 112.8 and 169.8 Gg CO2 eq, representing 4%, 8% and 11% for the year 2025, 2030 and 2035 respectively. The high mitigation option for cement is chosen.

ES 4.8 AFOLU mitigation assessment

ES 4.8.1 BAU scenario

AFOLU removals were estimated at 107,450 Gg CO_2 eq in 2010 to increase 121,575 Gg in 2015. In net terms at national level, net removals increased from 86,725 Gg CO_2 eq in 2010 to 100,497 Gg CO_2 eq in 2015. On this trend, Namibia's land sector will remain a sink but become CO_2 neutral under the scenario of increased harvest and use of the invader bush.

The assumptions made when working emissions for the BAU scenario for the LAND sector which governs mitigation are:

Land

- National programmes for the protection of Forest lands is deemed to reduce deforestation to a strict minimum with a loss of 7500 hectares annually to OWL.
- OWL will also stabilize as invasion of grassland in the southern part of the country is estimated to be not occurring due to rainfall being limiting. An area of 2500 ha annually is estimated to be converted to Forestland annually. A loss of 100 ha annually to Settlements has been estimated up to 2035.
- Cropland will reach 350,000 ha by year 2020 and is estimated to stay stable as this area is required for food production.
- With no invasion occurring, the Grassland area of 3.8 M ha will remain same. Exploitation of the invader bush in OWL are not expected to affect this land class as it will be primarily wood removal as opposed to full clearing.
- Settlements area will increase marginally by 100 ha an annual basis from OWL as inclusion from Cropland or Grassland is estimated not to occur.
- The area of Wetlands and Other lands is estimated to remain stable.

Other parameters

- Wood removals for fuelwood and poles will continue to occur and use rate has been kept same in the same trend between 2000 to 2010. Wood removal to produce charcoal and for export of fuelwood will also increase under the BAU scenario.
- The area disturbed due to burning is estimated at 2.5 % of total area of Forest Land, OWL and Grassland.

ES 4.8.2 Mitigation in the AFOLU sector

Mitigation in the AFOLU sector is considered plausible only in Forestland as the other categories do not offer the guarantee for them to be realised within the national context. The action is directed at the sustainable use of woody biomass, namely invader bush from the OWL land class. Present uses of invader bush consist of:

- Fuelwood
- Charcoal manufacture
- Burning for energy purposes in the manufacturing industry
- Production of pellets from invader bush in the Cheetah environment to protect the latter

- Animal feed
- Structural material for housing and kraals

It is also projected to use significant amounts of invader bush for producing electricity in lieu of imports of this commodity produced from Coal primarily (See Energy sector mitigation).

ES 4.8.3 Options for mitigation in LAND sector

Numerous options exist for mitigation within the LAND sector but only those having a potential to be successfully implemented and closely associated with the national circumstances have been assessed. These options are:

- Sustainable/reduction in removal of poles for construction of dwellings and kraals;
- Sustainable removal of invader bush for various purposes; and
- Reducing deforestation.

Sustainable/reduction in removal of poles

The use of poles has been regressing over time due to the shift from wood to other construction materials such as bricks and corrugated iron sheets. These actions are expected to lead to a decrease of the number of poles under the BAU scenario. Estimates of future removals and emissions avoided from poles are projected to be 920.3 Gg CO_2-eq in 2025, 1,012.0 Gg CO_2-eq in 2030 and 994.0 Gg CO_2-eq in 2035. These reductions represent 60%, 70% and 75% of BAU.

Sustainable harvest of invader bush for various purposes

As described above, the sustainable removal of invader bush to rehabilitate rangelands is a promising mitigation option which also provides for adaptation and preservation of biodiversity. Projected reduction in emissions is -569.3 Gg CO_2-eq in 2025, 1,945.4 Gg CO_2-eq in 2030 and 7,440.6 Gg CO_2-eq in 2025 representing -6%, 16% and 42% for the same years respectively. It is to be noted that the start of power plants using biomass in 2025 offsets the reductions of other measures and actually shows a slight increase of emissions over the BAU.

Emissions under the BAU scenario increased from 23,735 Gg CO_2-eq in 2025 to 38,345 Gg CO_2-eq in 2035, an increase of 62%. From no mitigation in 2025 with emissions being still at 28.5 Gg CO_2-eq, the reduction jumped to 13,394.9 Gg CO_2-eq in 2035. The combined level of mitigation from the two actions evolves from nil in 2025 to 35% in 2035 for the AFOLU sector.

ES 4.9 Waste mitigation assessment

Business As Usual Scenario: Under the BAU scenario, all solid waste from the high and low urban areas are landfilled while in rural areas, the solid waste is open burned. The projected amount of solid waste has been estimated as per the rate generated per capita and the projected population of the high urban, low urban and rural areas. This data is then fed in the IPCC 2006 software to estimate the resulting emissions.

Emissions are projected to be 232.3, 281.2 and 340.0 Gg CO_2-eq in 2025, 2030 and 2035.

ES 4.9.1 Mitigation options

There are numerous options for the valorisation of waste as a source of energy or raw material such as compost, while metals and plastic are recycled. These include:

- Recycling of plastic and metallic components after segregation;
- Composting through various fermentation pathways;
- Waste to energy projects via various channels and technologies;
- Production of biogas.

Systems coupling two or all four above options can be adopted for a holistic management of MSW and enabling the best management practice.

ES 4.9.2 Choice of Mitigation Option

Out of the various options presented above, the most attractive option in the short term and medium term appears to be the mix flaring and conversion of landfill gas (LFG) to electricity in high urban areas and segregation and composting in low urban and rural areas.

Collection and conversion of LFG to electricity/flaring

The landfills were developed in the 1980s such that LFG production is ongoing at varying rates across them. It is assumed that only 80% of the methane produced will be captured and either flared or converted to electricity. The potential for reduction of emissions through conversion to electricity/flaring is projected at 50.8 Gg CO_2-eq in 2025, 63.3 Gg CO_2-eq in 2030 and 77.7 CO_2-eq in 2035.

Composting

It is expected that 80% of the solid waste generated in both the low urban and rural areas can be recovered for composting. A gradual adoption rate of this practice is estimated for rural region with 25 % of waste composted in 2025, 50% in 2030 and 75% in 2035.This will result in an emission reduction of 72.3 Gg CO_2-eq, 101.0 Gg CO_2-eq and 135.1 Gg CO_2-eq in 2025, 2030 and 2035.

When cumulating all mitigation options for solid waste, the emissions reduction will reach 123.1 Gg CO_2-eq in 2025, 164.3 Gg CO_2-eq in 2030 and 212.8 Gg CO_2-eq in 2035. These reductions represent 53%, 58% and 63% of the BAU emissions.

ES 5. Other information considered relevant to the achievement of the objective of the Convention

ES 5.1 Transfer of Technologies

Some transfer of technologies took place concurrently with the implementation of mitigation and adaptation projects. In line with the updating of the mitigation and adaptation needs for more ambitious programmes for the transition to a low carbon economy and building resilience within a shorter timeframe, there still exist a big gap to fill to achieve readiness for implementation of the steps planned for implementing the Convention. A list of the most urgent needs related to technology, soft and hard, assessment and transfer for mitigation is provided in this report.

Regarding adaptation, the need also arises for the transfer of a multitude of technologies for various economic sectors. The ones necessitating most urgent action to safeguard livelihood and welfare of the poorer most vulnerable segment of the population are in the agriculture and water resources sectors. The prioritized technologies for agriculture are irrigation and water harvesting, conservation agriculture, crop diversification, use of improved indigenous crop germplasm, use of well adapted indigenous livestock breeds, increased seed and fertilizer (incorporating organic fertilizers) availability, shared water resource management, early warning systems, drought mitigation measures, restoration of rangelands and improved livestock management policies and strategies. Adaptation in the water resources sector will include increasing reservoir capacity, improve soil conservation, water recycling for reuse, increase water use efficiency, harvesting rainwater, use drought tolerant crops and desalination amongst others.

ES 5.2 Research and systematic observation

Though the scientific evidence indicates that climate has changed significantly over and above that caused by natural variability due to man-made (anthropogenic) interference in the climate system, (IPCC, 2014) climate change and its impacts are still not well understood by major components of the population of developing countries. There exists the need to undertake research to quantify the potential impacts at the local, national and regional levels to enable the proper development of practical solutions for adaptation and mitigation. To achieve this, the country must collect data/make systematic observations and undertake research to develop country specific emission factors for use in the compilation of its GHG inventory.

ES 5.3 Education, Training and Public awareness

To effectively address climate change adaptation and mitigation, it is essential that the managers of responsible and leading institutions, the wider stakeholder groups, the private sector and the targeted segments of the population are sufficiently educated, trained and aware of what is expected from them. Thus, education has to be formal and informal. Presently, climate change is only part of the tertiary curriculum as modules of some disciplines. The intent is to gradually include climate change as a component of the primary and secondary curricula and extend it in the tertiary curriculum to prepare the coming generations to adapt and mitigate.

It is recognized that a significant portion of the population lacks awareness on climate change issues they are exposed to notwithstanding their role in mitigation. This is due to lack of resources and a limited number of national experts to effectively deliver on this issue. It is planned to enhance public awareness programmes to maximize outreach, the final objective being to cover all segments of the population countrywide. This is deemed essential as the public needs to have access to the latest information to integrate them in the process and enable them to successfully participate in actions to be implemented.

ES 5.4 Capacity Building

Namibia has built some capacity for reporting to the Convention and on its implementation. However, with the changes in the standard of reporting, the transparency framework and the urgency of implementing the NDC, there still exist a large gap to fill. Much hope rests on the Capacity Building Initiative for Transparency (CBIT) project which is under preparation for approval by the GEF to make up for this lack of capacity. Technical capacity building concerns mainly mitigation and adaptation technologies earmarked in the respective chapters for the measures that are most prominent and prioritized in this communication and other reports submitted to-date. Capacity building also concerns overarching issues. As a developing country, Namibia needs robust institutional structures to take on and implement programmes and activities on climate change. Building human and institutional capacity to address climate change will be a fundamental component of the Namibian strategy on climate change. Capacity building for climate change will thus include further development and strengthening of personal skills, expertise of national experts and of relevant institutions and organizations on adaptation, mitigation and reporting. Capacity building will involve a wide group of stakeholders, including the government, NGOs, research institutions, local communities and the private sector.

ES 5.5 Information and networking

Climate change is a global problem requiring the cooperation of all to tackle it successfully. Namibia as a Party to the Multilateral Environmental Agreements and various other Protocols and Agencies aims to preserve the environment within the sustainable development Agenda. This is in line with the Convention. To attain this objective, Namibia has identified and included the priority actions on the international and national fronts in this report.

ES 6. Constraints and Gaps, and related Financial, Technical and Capacity Needs

ES 6.1 Reporting

The enhancement of the reporting requirements demands for higher standards and a permanent framework to enable the sustainable production of these reports while guaranteeing their quality. In addition, there is a need to develop and establish permanent systems for monitoring, reporting and verifying mitigation actions (MRV) and other activities related to the Convention.

During the exercise of strengthening of the existing institutional arrangements, numerous and very daunting challenges cropped up. The most urgent ones were Insufficient capacity of the coordinating body as well as lack of institutional and technical skills within the different thematic areas of the NC, maintain a motivated permanent coordinating body and/or personnel, Staff scarcity / unavailability in collaborating institutions due to their already overloaded schedules and staff turn-over and Lack of incentives and adequate funds to develop and maintain the system in place

ES 6.2 GHG inventory

Namibia, as a developing country, has its constraints and gaps that need to be addressed to produce better quality reports for reporting to the Convention. The following problems were encountered during the preparation of the national inventory of GHG emissions:

- Information required for the inventory had to be obtained from various sources as no centralized archiving system has been developed for GHG inventory preparation;
- Almost all of the AD were not in the required format for feeding in the software to make the emission estimates;
- End-use consumption data for all the sectors and categories were not always readily available;
- Reliable biomass data such as timber, fuelwood, wood waste and charcoal consumed or produced were not readily available and were estimated;
- Inconsistencies were found when data were collected from different sources;
- Solid waste characterization data, amount generated and wastewater generated are not regularly measured and had to be derived;
- EFs have to be derived to better represent national circumstances and improve estimates;
- National experts need more training on the GHG estimation software to become fully conversant with them.

ES 6.3 Mitigation and Adaptation

Implementation of mitigation and adaptation measures and actions is a major challenge for the country in view of the multiple constraints and gaps that exist in various areas, namely at the institutional, organizational and individual levels. There is a need to create the enabling environment in the country. Needs also exist for improving the technological assessment and transfer for mitigation and the technical capacity of national experts. Further assessments still have to be undertaken to identify more prominent measures and actions as well the prioritize those with the highest potential for successful implementation.

Barriers will have to be removed to speed up the process of implementation of mitigation and adaptation, and the preparation of project proposals for funding.

The appropriate funding amounts and timing are important features to take into consideration when these measures and actions, especially the implementation aspect, are aligned with the country’s development strategy and agenda. Implementation is even more difficult as a result of the significant amounts of sustained funding required to develop and implement mitigation and adaptation projects. Up to now, Namibia has not tapped much funding to support its mitigation strategy. There is need for these shortcomings to be corrected by the international community through further consolidation of the Green Climate Fund for the latter to fully fulfill its roleA list of actions requiring funding have been provided in the BUR3.

ES 6.4 Capacity Building and Financial Needs

Namibia's needs to implement the Convention relates to financial, technical, and capacity building primarily. Technical capacity building concerns mainly mitigation and adaptation technologies While several other overarching issues have to be addressed for successful implementation of the Convention.

As a developing country, Namibia needs robust institutional structures to take on and implement programs and activities on climate change. Building human and institutional capacity to address climate change will be a fundamental component of the Namibian CCSAP. Capacity building for climate change will thus include further development and strengthening of personal skills, expertise and of a wide group of stakeholders from relevant institutions and organizations on adaptation, mitigation and reporting.

The NCCP highlighted that government consider and explore a range of multi- and bilateral funding options including grants, concessional and non-concessional loans, as well as market-based instruments. The NCCP also emphasises the importance of evidence-based strategies and action plans, and observes that "Climate change research needs to be properly coordinated, and its benefits optimised to meet the needs of decision-makers in Namibia". The CCSAP on the other hand identified the need to maximise government financing instruments at the national and local levels; leverage private sector investment; and access scaled-up, new and additional (external) financial resources. The need also exists to develop assessment tools to inform decision-making, and to establish partnerships among national and local government agencies, business, professional and other private groups, community-based organisations, academic and scientific organisations and civil society organisations in order to realise its objectives.

1. Introduction

Namibia ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1995 as a Non-Annex 1 Party. In doing so, Namibia is obligated by the Convention to namely, report as per Article 4, paragraph 1 and on implementation of the Convention through the development of policies and measures designed to mitigate and adapt to climate change. Various policies and strategies have been developed to fit in the new development agenda geared towards a low emissions economy in line with the latest decisions of the Conference of the Parties (COP). The Global Environment Facility (GEF) through the United Nations Development Program (UNDP) country office provided funding to produce most of the country's national reports. These are Namibia's Initial National Communication (INC), Second National Communication (SNC), Third National Communication (TNC) as well as the present Fourth National Communication (NC4) to the UNFCCC, which are commitments of the country to fulfill its obligations under the Convention. Over and above these national communications, Namibia has also met its additional obligations, following COP decisions, in preparing and submitting three Biennial Update Reports and its Intended Nationally Determined Contribution (INDC) according to the time schedules.

Namibia is committed to contribute to efforts of the international community for combating climate change. In this context, the country has strengthened the existing institutional arrangements, has engaged in the development of a greenhouse gas inventory management system (GHGIMS) and is developing an appropriate Measurement, Reporting and Verification systems (MRVs) to better implement and track mitigation of climate change in view of stabilizing greenhouse gases in the atmosphere at a the level not detrimental to the proper functioning of natural ecosystems as earmarked in Article 2 while investing on adaptation to climate change to build resilience of the population in the medium to longer term. The institutional arrangements, GHGIMS and MRVs are more fully described later in this national communication as well as measures and steps taken and planned to meet the objectives of the Convention.

The NC4 project built on and improved previous work done under the framework of National Communications (NCs) and Biennial Update Reports (BURs) and INDC. The situation has not evolved significantly as the Namibian economy remains natural resource based and is extremely sensitive to climate change impacts. The direct effects of climate change have been seriously felt on various economic sectors such as water, agriculture, fisheries, ecosystems, biodiversity, tourism, coastal zone, health and energy in recent years. These impacts stemmed from prolonged droughts which in turn affected the economy and resulted in lower than normal Gross Domestic Production (GDP). This situation is not expected to improve in the coming years but could rather worsen, given that the global temperature increase projected by Intergovernmental Panel on Climate Change (IPCC) is above the critical limit of 2^{o}C. This will disrupt the proper functioning of natural ecosystems that are the driving factors of the Namibian economy.

Namibia intends to intensify its efforts to fully transform its economic development to one with a low carbon footprint while consolidating investments to increase its resilience in light of the latest climate change projections. However, resources are lacking to implement planned measures and steps. It is thus of utmost importance that the international community reaches a global agreement as soon as possible and provides for sustainable support in a timely manner to Non-Annex I Parties to enable them meet their obligations and commitments for successfully addressing the threat posed by climate change.

2. National Circumstances

2.1 Introduction

Namibia's development is guided by its long-term National Policy Framework, Vision 2030, which transcribes into National Development Plans for 5-year periods, and recently through the Harambee Prosperity Plan (HPP). The country is currently in its Fifth National Development Plan (NDP5) that outlines a development strategy that aims at improving the living conditions of every Namibian through sustainable development and a low carbon economy. The vision is to have a prosperous and industrialized Namibia, developed by its human resources, enjoying peace, harmony and political stability.

This section presents the national circumstances of Namibia, detailing the national development priorities, objectives and circumstances that serve as the basis for addressing issues relating to climate change.

2.2 Convention Obligations

Namibia ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1995 as a Non-Annex 1 Party, and as such, is obliged to report certain elements of information in accordance with Article 4, paragraph 1 of the Convention. These elements include:

(a) A national inventory of anthropogenic emissions by sources and removals by sinks of all greenhouse gases (GHG) not controlled by the Montreal Protocol, to the extent its capacities permit, using comparable methodologies to be promoted and agreed upon by the Conference of the Parties (COP);

(b) A general description of steps taken or envisaged by the Party to implement the Convention; and

(c) 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 three national communications (NCs), namely: the INC in 2002; the SNC in 2011; and the TNC in 2015. These reports were prepared with support from the Global Environmental Facility (GEF) through the United Nations Development Programme (UNDP) country office. The Cancun Agreements arrived at during COP 16 in 2011 stipulated that NC reports by non-Annex I Parties, including national GHG inventories, be enhanced to include information on mitigation actions and their effects as well as support received. It was also decided that developing countries, consistent with their capabilities and the level of support provided for reporting, should submit BURs. The latter, containing updates of national GHG inventories, inventory report and information on mitigation actions, needs and support received and Institutional Arrangements are produced every two years, with the first one due in December 2014 as decided in COP 17. Namibia also met this obligation and submitted its BUR1 during COP 20 in Lima in 2014 and further followed up with submitting its second and third BURs in 2016 and 2019 respectively, making Namibia one of the most compliant Non-Annex 1 Party to the Convention, in terms of reporting.

Reporting guidelines agreed during COP 8 for the preparation of NCs from Parties not included in Annex I to the Convention and contained in decision 17/CP.8 have been adopted for the preparation of this report.

The multi-sectoral National Climate Change Committee (NCCC), chaired by the Ministry of Environment and Tourism (MET), provided the overall oversight and advisory role for the implementation of the Fourth National Communication (NC4) project. Like for previous NCs and BURs, NC4 was coordinated by the Climate Change Unit (CCU) of the Department of Environmental Affairs (DEA) of the MET, which is responsible for overseeing the coordination of climate change issues in Namibia in its role as national focal point of the Convention.

2.3 Institutional Arrangements

The Cabinet of Namibia is the Government entity entrusted with the overall responsibility for the development of Policies, including those on climate change. The NCCC oversees the implementation of the climate change policy, including the preparation of the reports for submission to the Convention, and plays an advisory role to Government on climate change issues. It comprises representatives of the various ministries and other stakeholders such as the private sector and NGOs amongst others. The NCCC was established in 1999 by a Cabinet directive to advise it on climate change issues, including reporting obligations. MET, the official government agency acting as national focal point of the Convention, is responsible for coordinating and implementing climate change activities, including the preparation of both NCs and BRs to enable the country to meet its reporting obligations. This is done through the Climate Change Unit (CCU) established within the DEA. Being a formalized and multi-sectoral committee, the NCCC provides the necessary support to the CCU by advising and guiding it for sector-specific and cross-sector implementation and coordination of climate change activities.

The NCCC is chaired by MET and the deputy chair is the National Meteorological Service of the Ministry of Works and Transport. The NCCC reports to the Executive Director of MET via the head of the DEA. The NCCC has the powers to establish working groups and subcommittees as required for implementing and conducting specific climate change activities. Such working groups have been active and very useful for overseeing and providing guidance on the different thematic areas during the preparation of previous NCs. Given that climate change has a bearing on all socio-economic sectors, various Ministries, Organizations and Agencies actively address climate change related issues either solely or in collaboration with other stakeholders as required. The CCU within MET usually directly assists these different bodies with planning, development, implementation and coordination of the activities at the local, regional and national levels. The collaboration of existing local and regional structures is secured for supporting implementation and coordination at the level required.

These existing arrangements worked well for the preparation of the first three submitted national communications. Preparation of these national communications was on an *ad-hoc* basis and did not require a permanent set-up that would have proven too onerous for the country being given the scarcity of resources. Thus, reporting on the different thematic areas was outsourced and the CCU of MET overlooked the whole process until the final report had been circulated, reviewed and approved by all stakeholders concerned for submission to the Cabinet for final clearance and to the COP. With the enhancement of the reporting requirements that came into force since the advent of the BUR and also the required higher standards of the national communication, these past institutional arrangements have shown their limitations. The present situation demands for a permanent structure to enable the sustainable production of these reports while guaranteeing their quality. In addition, there is a need to develop and establish permanent systems for monitoring, reporting and verifying mitigation actions within the transparency framework of the Paris Agreement. And for other activities related to the Convention so that Namibia may honour its reporting obligations on both the national and international fronts.

Conscious that the existing frameworks are no longer appropriate and suitable under these new circumstances, MET embarked on a full exercise of reviewing the existing set-up towards developing and implementing new and more robust institutional arrangements for meeting the enhanced and more frequent reporting obligations, including the production of BURs and revision of Nationally Determined Contributions (NDCs).

One important decision was to shift from outsourcing the different elements of the Convention reports to having them produced in-house. The exercise started after the decision taken during COP 17 and the preparation of the BUR1 in 2014. While the NCCC and CCU were kept in place, an institutional mapping was done by the latter, which kept the responsibility of coordinating the production of the reports. The mapping exercise enabled the identification of all stakeholders who have a role and contribution to bring in the production of better quality NCs, BURs, NDCs and the forthcoming Biennial Transparency Reports (BTRs) and in the eventual MRV systems. A round of one on one consultations was done to engage and buy in stakeholders and this was followed by formalization through official letters inviting nominations of representatives. Nominees were then called for a brainstorming session to present them the new needs for meeting reporting standards, discuss implications for the institutions and agree on their role, contribution and responsibilities, namely for the major GHG inventory and mitigation components. It became evident during these consultations that there existed a serious lack of capacity. The consensus was to try to produce the next BUR, fully or partially, followed by future reports, with minimal outsourcing. However, this objective could not be met, and outsourcing was once more resorted to until sufficient capacity is built for the national experts to take over fully this exercise. The full participation of most of the stakeholders benefited on capacity building to enable them assume their additional responsibilities.

Within the planned institutional arrangements, there will be a sharing of responsibilities with the coordinating body taking on most of the planning, preparation, quality control, archiving, evaluation and validation with the other stakeholders concentrating on the more technical components, including data collection and provision of other information to the Consultant for compilation of the GHG inventory, reviewing draft reports and validation of these.

During the exercise of strengthening of the existing institutional arrangements, numerous and very daunting challenges cropped up. The most urgent ones were:

- Insufficient capacity of the coordinating body as well as lack of institutional and technical skills on the different thematic areas of the NC;
- The need to maintain a motivated permanent coordinating body and/or personnel;
- Staff scarcity / unavailability in collaborating institutions due to their already overloaded schedules and high staff turn-over; and
- Lack of incentives and adequate funds to develop and maintain the system in place.

It was also evident that the development and implementation of robust institutional arrangements will take substantial time to become fully operational and to run smoothly. It is anticipated that this will take two to three rounds of BURs and NCs. The revamped institutional arrangement is presented in Figure 2.1.

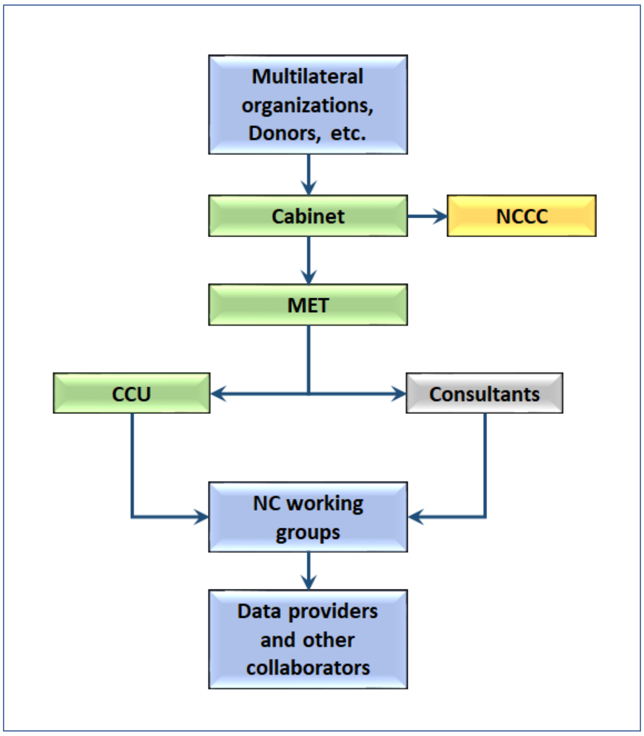


Figure 2.1. Institutional arrangements for implementing climate change activities

2.4 Geographical Characteristics

Namibia is situated in the southwestern region of the African continent and lies between latitude 17° and 29°S and longitude 11° and 26°E. The country covers a land area of 825,418 km^2 and has a 1,500 km long coastline on the South Atlantic Ocean. It is sandwiched between Angola to the North and South Africa to the South and also borders with Zambia to the far North, and Botswana to the East.

The physical geographic context of Namibia is determined by its position at the border of the continental shelf of the Southern African subcontinent in the climatic sphere of influence of the Tropic of Capricorn and the cold Benguela Current. The land surface ascends from the Namib Desert to the mountains of the continental border range with peaks at 2,606 metres above mean sea level (mamsl). To the East and North the country then descends into the Kalahari basin with a mean altitude of 1000 mamsl.

2.5 Climate

Namibia is one of the biggest and driest countries in sub-Saharan Africa. It is characterized by high climatic variability in the form of persistent droughts, unpredictable and variable rainfall patterns, variability in temperatures and scarcity of water. The climate of Namibia is a consequence of the country's location on the Southwestern side of the African continent, situated at the interface between different climate systems. The cold Benguela Current along the West coast and Namibia's position, straddling the sub-tropical high-pressure belt, determine the main features of the climate. The Benguela Current brings in cold water to its western shores. The climate of the Northern part of the country is influenced by the Inter-Tropical Convergence Zone (ITCZ) and the Mid-Latitude High Pressure Zone, while the Southern part of the country lies at the interface between the Mid-Latitude High Pressure Zone and the Temperate Zone. The different seasons experienced in Namibia are driven by the northward and southward movements of these zones, in response to the apparent movement of the sun.

The cold water from the Western shores (Benguela Current) is adverted from the South and is partly driven by a high-pressure system over the South Atlantic. The combination of cold water and high pressures leads to subsidence of cold dry air over much of the country which commonly suppresses rainfall. This situation is dominant during most of the year, except in summer when heating of the continent is greatest and the southerly position of the ITCZ draws moisture and rainfall from the tropics over northern and eastern Namibia. Therefore, the ITCZ and the Temperate Zone bring rainfall, while the Mid-Latitude High Pressure Zone brings drier conditions.

The movement of the ITCZ towards the south during the Namibian summer results in the rainfall season, normally starting in November and ending in April. In the far south, the Temperate Zone moves northwards during the winter, resulting in the winter rains that occur in the far Southwest of the country. Small variations in the timing of these movements result in the considerable differences in the weather experienced in Namibia from one year to the other.

Namibia is one of the driest countries in southern Africa with mean annual rainfall ranging from just above 600 mm in the Northeast to less than 25 mm in the Southwest and West of the country

The rainfall isohyets generally follow a gradient from the North-East to the Southwest. There are exceptions to this general pattern, e.g. the maize triangle of Tsumeb, Grootberg and Otavi receives more rainfall than would be expected in that geographic location. The reason for this is the undulating topography, which gives rise to orographic rainfall. On the other hand, the coastal zone receives almost no rainfall at all.

In the Western part of the Namib Desert, coastal fog is an important source of water for the desert fauna and flora. Fog precipitation is five times greater than that of rain and is far more predictable.

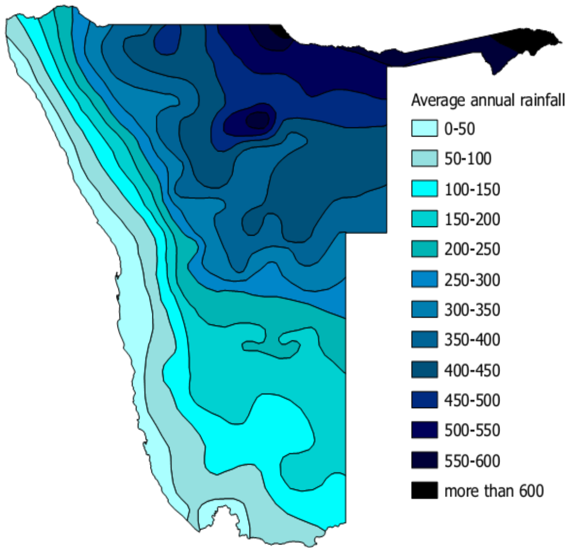


Figure 2.2. Distribution of average annual total rainfall in Namibia

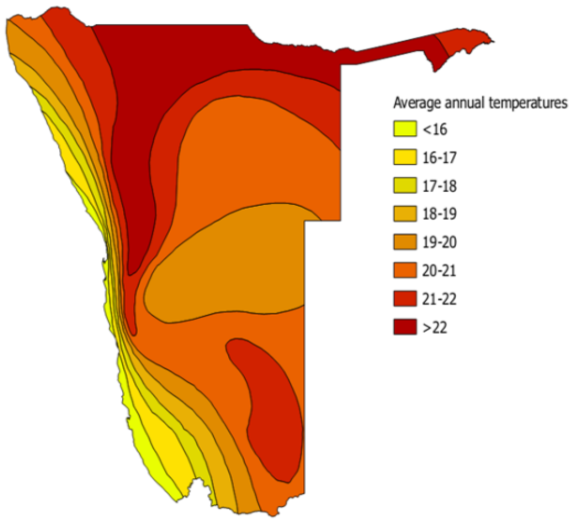


Figure 2.3. Average annual temperature in Namibia

Namibia is characterized by high temperatures (Figure 2.3). Apart from the coastal zone, there is a marked seasonal temperature regime, with the highest temperatures occurring just before the wet season in the wetter areas or during the wet season in the drier areas.

The lowest temperatures occur during the dry season months of June to August. Mean monthly minimum temperatures do not, on average, fall below 0°C. However, several climate stations in the central and southern parts of Namibia have recorded individual years with negative mean minimum monthly temperatures, and individual days of frost occur widely.

From a hydrological point of view, Namibia is an arid, water deficient country. High solar radiation, low humidity and high temperatures lead to very high evaporation rates, which vary between 3800 mm per annum in the south to 2600 mm per annum in the north. Over most of the country, potential evaporation is at least five times greater than average rainfall. In those areas where rainfall is at a minimum, evaporation is at a maximum. Surface water sources such as dams are subject to high evaporation rates.

Wind speeds are generally low in Namibia, only at the coast do mean wind speeds exceed 3 m/s, and it is only at isolated climate stations inland, e.g. Keetmanshoop, that the mean wind speeds exceed 2 m/s. These winds, and the occasional stronger gusts, do not cause any real problem apart from some wind erosion in the drier parts of the country during the driest part of the year. Away from the coast, relative humidity averages between 25% and 70%, with the dry season being less humid than the wet.

2.6 Biodiversity

Despite its very dry climate, Namibia holds a remarkable variety of species, habitats and ecosystems ranging from deserts to subtropical wetlands and savannas. Namibia is one of the very few countries in Africa with internationally recognized "biodiversity hotspot". Namibia's most significant "biodiversity hotspot" is the Sperrgebiet, which is the restricted diamond mining area in the Succulent Karoo floral kingdom, shared with South Africa. The Succulent Karoo is the world's only arid hotspot. It constitutes a refuge for an exceptional level of succulent plant diversity, shaped by the winter rainfall and fog of the Southern Namib Desert. A large portion of its plants is endemic (MET, 2001). Other notable features of the rich Namibian biodiversity include:

- The world's largest populations of cheetah and free-roaming black rhino, and increasing populations of other globally threatened mammals
- An entire Coastline under national park status, and a network of national parks covering over 17% of the country
- The Benguela Current Large Marine Ecosystem, which graces Namibia's 1,500 km coastline with cold, nutrient-rich waters and sustains abundant shoals of fish and other marine and bird life
- It should also be noted that by end 2017, about 20% of the country are under community-based resource management including 83 communal conservancies and 32 community forests

2.6.1. Threats to Biodiversity

The most significant threats to the biodiversity of Namibia are:

- Unsustainable Water Uses mainly through large scale irrigation, pollution, damming and over-abstraction of groundwater.
- Climate change, mainly through increased drought and flood events; shifts in vegetation types and species distribution; and effects on the Benguela Current system.
- Mining and prospecting, especially in ecologically sensitive areas (including offshore) and through habitat loss and destruction, and increased demand for water and electricity.
- Unsustainable Land Management Practices leading to soil erosion, land degradation, deforestation and bush encroachment.
- Alien Invasive Species, which are causing species loss and ecosystem simplification and breakdown.

2.7 Human Wildlife Conflict with increasing damages to community livelihoods in terms of crop destruction and Water Resources

Namibia is the driest country in Southern Africa. Water is a scarce resource and one of the major primary factors limiting development of the country. The effects of climate change, rapid population growth, and rural exodus pose additional challenges and threaten people's livelihoods as well as the balance of the ecosystems. Namibia's rainfall is skewed, with the Northeast getting more that the West and Southwestern parts of the country. Namibia's international boundaries, both northern and southern are marked by perennial rivers, the Kunene in the northwest, the Okavango in the central north and the Zambezi and Kwando rivers in the northeast. The Orange River marks Namibia's southern border. These rivers are all shared with neighbouring riparian states with an obligation for them to be managed and used in terms of the relevant rules of international water law.

Of the water that Namibia receives as precipitation, it is estimated that only 2% ends up as surface run-off and a mere 1% becomes available to recharge groundwater. The balance of 97% is lost through direct evaporation (83%) and evapotranspiration (14%). Rainfall often evaporates before it reaches the ground. Another source of moisture comes from fog in the cooler coastal regions where it is an extremely valuable source of water to desert fauna and flora.

The primary sources of water supply are perennial rivers, surface and groundwater (alluvial) storage on ephemeral rivers, and groundwater aquifers in various parent rocks. Additionally, unconventional water sources have been adopted to augment the limited traditional sources. About 45% of Namibia's water comes from groundwater sources, 33% from the Border Rivers, mainly in the north, and about 22% from impoundments on ephemeral rivers (Christelis and Struckmeier, 2001).

2.8 Agriculture and Forestry

The share of Agriculture and Forestry in GDP (current prices) stood at 3.3% in 2015, down 0.6% from the previous year's level. Nonetheless, sustained efforts have continued to move the country from an exporter of live animals to an exporter of value-added agricultural goods.

Despite its relatively modest contribution to GDP, agriculture remains a strategic sector as it impacts directly on the livelihood of more than 70% of the population and employs about one third of the workforce of Namibia. The sector is crucial for its contribution to food security as it addresses the livelihood concerns of a significant section of the Namibian population. In 2016, the proportion of food insecure individuals in Namibia stood at 25%. The production of white maize, wheat, pearl millet and livestock including cattle, goat and sheep is divided in the intensive commercial production units and the extensive communal production system. The commercial sector though occupying 44% of land involves only 10% of population while the communal sector occupies 41% of the land and involves 60% of the population.

Approximately 48% of Namibia's rural households depend on subsistence agriculture (NDP4). Most rural communities, particularly in the higher rainfall areas of the North, depended directly on forest resources for use as fuel wood, building materials, fodder, food and medicine. However, this has changed significantly now as it is necessary to ensure the systematic management and sustainability of forest resources.

The variability of climate, particularly rainfall, has a profound impact on the availability aspect of food security. The recent droughts at the start of this decade have highlighted this important feature of the Namibian society. According to the NDP5 report, a three-year long drought that lasted between 2013 and 2016 led to low production in both the crop and livestock farming sub-sectors. The livestock sub-sector contracted by 13% in 2015 from a positive 13.9% in 2014 due to a foot and mouth disease outbreak and fluctuations in prices of cattle and small livestock.

A recent 2013 survey by the FAO has revealed that 330,000 people particularly in the poor north-western areas are food insecure and a further 447,000 moderately food insecure. This situation also puts pressure on forest resources.

2.9 Fisheries

Namibia has one of the most productive fishing grounds in the world, primarily due to the presence of the Benguela current. The upwelling, caused by the current, brings nutrient-rich waters up from the depths that stimulate the growth of microscopic marine organisms. These in turn support rich populations of fish, which form the basis of the marine fisheries sector. As is the case in other upwelling systems, relatively few species dominate, and their abundance can vary greatly in response to changing environmental conditions. Over 20 commercially important fish species are landed using various fishing methods. The offshore commercial fishery represents the largest component of the fishing industry. Small pelagic (open water) species (pilchard, anchovy and juvenile mackerel) and lobster are fished along the shallower onshore waters on the continental shelf. Large pelagic species including adult mackerel, demersal (bottom dwelling) hake and other deep-sea species, such as monkfish, sole and crab, are fished in the waters further offshore.

Since independence in 1990, the fishing industry has grown to become one of the pillars of the Namibian economy. The commercial fishing and fish processing sectors significantly contribute to the economy in terms of employment, export earnings, and contribution to GDP. The fishery sector contributed 4.6% in 2009, compared to 3.7% in 2010, representing a 20% reduction. Its contribution increased by 0.2% to 3.9% in 2012. As for 2013, the GDP contribution was 3.45% indicating a decrease of 0.45%. The sector is a substantial export earner, with over 85% of Namibia's fish output destined for international markets, contributing 15% of Namibia's total exports.

2.10 Tourism

Namibia's unique landscapes and biodiversity support a rapidly developing tourism industry. Travel and tourism's contribution to the Namibian economy is illustrated by their combined direct and indirect impacts. According to the Tourism satellite account, the tourism sector in 2015 is estimated at N$5.2 billion of direct value added and more than 44,700 job directly created. However, when considering both direct and indirect contributions, the tourism sector's contribution rises to N$15.1 billion, representing 10.2% of overall GDP and 100,700 jobs, equivalent to 14.5% of total employment. Preliminary estimates for 2016 show an improvement on these figures: N$16.7 billion, equivalent to 10.5% of overall GDP and 101,000 jobs equivalent to 14.9% of total employment (NTB, 2015).

2.11 Communal-area conservancies

According to the state of community conservancy report of 2017, community conservation in Namibia covers 166,267 km^2, which is about 53.2% of communal land with an estimated 212,092 residents and approximately another 6,170 members of the Kyaramacan association who live in the Bwabwata National Park. From the beginning of 1990 to the end of 2017, community conservation contributed an estimated N$7.11 billion to Namibia's net national income. During the year 2017 alone, community conservation generated over N$132 million in returns for local communities and facilitated 5,350 jobs.

As of the end of 2017 there were 83 registered communal conservancies and one community conservation association in a national park, which is managed like a conservancy. A total of 19 concessions in national parks or on other state land held by 23 conservancies of which some conservancies share concessions. By end 2017, conservancies covered 163,151 km^2 which is equivalent to 19.8% of Namibia's total land surface (NACSO, 2017).

2.12 Community forests

At the end of 2017 there were 32 registered community forests, covering a total of 30,828 km^2 of Namibia, 89% of which overlaps with conservancies. The use of all indigenous plant resources is regulated by the Directorate of Forestry (DoF) within the Ministry of Agriculture, Water and Forestry. The Forestry Act of 2001 and the Forestry Amendment Act of 2005 enable the registration of community forests through a written agreement between the Directorate and a committee elected by a community with traditional rights over a defined area of land. The agreement is based on an approved management plan that outlines the use of resources. All residents of community forests have equal access to the forest and the use of its produce. Communities have the right to control the use of all forest produce, as well as grazing, cropping and the building of infrastructure within the classified forest (NACSO, 2017).

2.13 Mining

Namibia is known world-wide for producing gem quality rough diamonds, uranium oxide, special high-grade zinc and acid grade fluorspar. As well, Namibia produces gold bullion, blister copper, lead concentrate, salt and dimension stone. According to the Chamber of Mines annual review report of 2018, mining is one of the major contributors in Namibia's national economy with 14% of the country's GDP in 2018. The sector's contribution has grown by 22% from 2017, where it contributed 13.3%.

2.14 Manufacturing

Namibia's manufacturing sector is inhibited by its small domestic market, dependence on imported goods, limited supply of local capital, widely dispersed population, small skilled labour force and high relative wage rates, and subsidized competition from South Africa. The manufacturing sector is estimated to have recorded a slow growth of 1.3% in real value added for 2017 compared to a strong growth of 5.6% recorded in 2016. The slow performance in this sector is mainly attributed to the decline in the meat processing, other food products and textile and wearing apparel (Annual National Accounts, 2017).

2.15 Energy

On the supply side, Namibia currently has three electricity power stations, these include: the Ruacana hydroelectric power station with a generation capacity of 240 Megawatts (MW), which depends on the inflow of rainfall from the catchment areas in Angola; the Van Eck coal power station with a production capacity of 120 MW with coal imported from South Africa; and the Paratus diesel plant with a capacity of 20 MW. This translates to a total of 380 MW. Current local electricity peak demand stands at 656 MW, exceeding the local generation capacity of 484 MW at peak (NDP5). The local supply does not meet the demand. Currently, Namibia imports most of this difference from South Africa and other Southern Africa Development Community (SADC) member states. A special arrangement between the Namibian power utility NamPower and ESKOM, the South African Power utility, enables Namibia to buy and utilize the surplus energy from South Africa at affordable rates. NamPower also imports on a smaller scale from Zambia for supply to the Caprivi region and exports on a small scale to Angola and Botswana (Annual National Accounts, 2012).

2.16 Transport

Namibia's road network is regarded as one of the best on the continent with road construction and maintenance being at international standards. Namibia has a total road network of more than 64,189 km, including 5,477 km of tarred roads which link the country to its neighbours Angola, Botswana, South Africa, Zambia and Zimbabwe. The management and maintenance of the national road network is under the responsibility of the Roads Authority governed by the Roads Authority Act of 1999 (Act 18 of 1999).

The country has two ports handling imported and exported merchandise and servicing the fishing industry. The only deep-sea harbour is Walvis Bay in the Erongo Region. The other harbour is Luderitz in the Karas Region. The Port of Walvis Bay receives approximately 3,000 vessels each year and handles about 5 million tonnes of cargo.

Passenger transport is mainly carried out by minibuses and sedans and is increasing in intensity. For businesspeople and tourists, air travel has become a more important means of transport to bridge the long distances. As of December 2013, Namibia had a total of 300,045 vehicles, representing an increase of 66,405 as compared with March 2007, when there was a total of 233,640. Out of the total number of vehicles 43.8% of them are light passenger motor vehicle (less than 12 persons), closely followed by light load vehicle (GVM 3,500 kg or less), with 43.5%.

The railway network comprises 2,382 km of narrow-gauge track with the main line running from the border with South Africa via Keetmanshoop to Windhoek, Okahandja, Swakopmund and Walvis Bay. Omaruru, Otjiwarongo, Otavi, Tsumeb and Grootfontein are connected to the northern branch of the railway network.

2.17 Waste

Namibia, as a medium income country with a growing wealthy urban middle class and significant urban drift, is feeling the pressure of amounts of waste generated on its facilities throughout the country and more especially in the urban areas. Solid municipal waste is dumped in landfills or open dumps while almost all urban settlements are connected to reticulated waste-water treatment systems. Management of the landfills and dumps are not at the best standards and very often, the waste is burnt in the open dumps to reduce the volume and health risks. Additionally, in most areas there is no segregation of waste and no separate landfills or dumps implying that industrial waste is dumped along with municipal waste. MET is responsible for managing solid waste. To this end, Namibia has developed and is currently enforcing the solid waste management strategy which aims at better management of solid waste in rural and urban areas.

2.18 Economic Growth

According to the National Accounts estimates, compiled by NSA in 2017 the domestic economy is estimated to have registered a contraction in real value-added of 0.9% compared to a growth of 0.6% recorded in 2016. This is the lowest rate recorded over the last 10 years. The drop was attributed to a weak performance in the secondary and tertiary industries that recorded declines in real value-added of 6.7% and 1.4% respectively. However, on the backdrop of good rainfall and an increase in production of major export commodities, the primary industries in 2017 registered a strong growth of 10.6% in real value-added.

Gross National Income (GNI) measures national income generated by the Namibian factors of production, which are labour, land and capital, both inside and outside of Namibia. Over the period 2007 to 2017, Gross National Disposable Income (GNDI) has been consistently higher than the GNI because of net inflows in current transfers that have been influenced mainly by high SACU receipts. Gross National Income stood at N$ 173.88 billion in 2017 as compared to N$ 162.18 billion recorded in 2016, representing an increase of 7.2 percent in nominal terms. GNDI improved to N$ 191.95 billion in 2017 from N$ 178.79 billion of the preceding year.

2.19 Population

According to the 2016 Namibia Inter-censal Demographic survey, the total population of Namibia was estimated at 2,324,388 people. Woman outnumbered man with 1,194,634, compared to 1,129,754 male individuals. The age composition of the Namibian population indicates that 14% of the population is under the age of 5 years, 23% between the 5 and 14 years, 57% between the 15 - 59 years, and only 7% of 60 years and above. A total of 43% of Namibia's population lived in urban areas with 57% in rural areas. The urban population grew by 49.7% between 2001 and 2011, while the rural counterpart decreased by 1.4% over the same period. This trend illustrates the high rate of rural-urban migration. The population density is low at 2.6 people per square kilometre in the Khomas Region, where the nation's capital is situated and has the highest population, followed by the northern regions. In Namibia 56% of households are headed by males and 44% by females.

2.20 Health

Namibia's provision of health services is shared between the public and the private sectors, the latter focusing on urban areas. Infant and child mortality is comparatively low, but the maternal mortality ratio has increased, even though over 70% of births take place in hospitals. General life expectancy has not improved, partly because of the HIV/AIDS epidemic. Malnutrition levels in children under the age of five years are as high as 38% in some regions. The five leading causes of inpatient deaths (all age groups) are HIV/AIDS, diarrhoea, tuberculosis, pneumonia and malaria.

Malaria is one of the major health problems. However, year-on-year incidences of malaria are highly variable, and closely correlated with the prevailing temperature, rainfall and humidity. Malaria is endemic in parts of the north-central and north-eastern regions. In contrast, in the north-western and parts of central Namibia, malaria transmission is seasonal and follows the onset of rains, these unstable occurrences increase the risk of malaria epidemics. Approximately 15% of the population aged 15-49 is living with HIV/AIDS, but the infection level appears to have stabilized. Seven per cent of all people living with HIV/AIDS are under the age of 15, and 60% are women. The very high incidence of tuberculosis in Namibia is fuelled by the HIV/AIDS epidemic, which has reduced life expectancy from 62 years in 1991 to 49 years.

3. Greenhouse Gas Inventory

3.1 The Inventory Process

3.1.1. Overview of GHG inventories

Under Article 4.1 (a) of the Convention, each Party has to develop, periodically update, publish and make available to the Conference of the Parties, 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, to the extent its capacities permit, using comparable methodologies to be promoted and agreed upon by the Conference of the Parties.

The INC and SNC of the Republic of Namibia to the UNFCCC included the National Inventory of greenhouse gases 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 carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), oxides of nitrogen (NO_x), sulphur dioxide (SO_2), non-methane volatile organic compounds (NMVOCs) and the precursor carbon monoxide (CO). A third Inventory has been compiled using a mix of Tiers 1 and 2 for the BUR1 and submitted to the UNFCCC in 2014. The fourth, fifth and sixth inventories have been submitted as stand-alone national inventory reports (NIR). The IPCC 2006 Guidelines and software were used for compiling these 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 3.1.

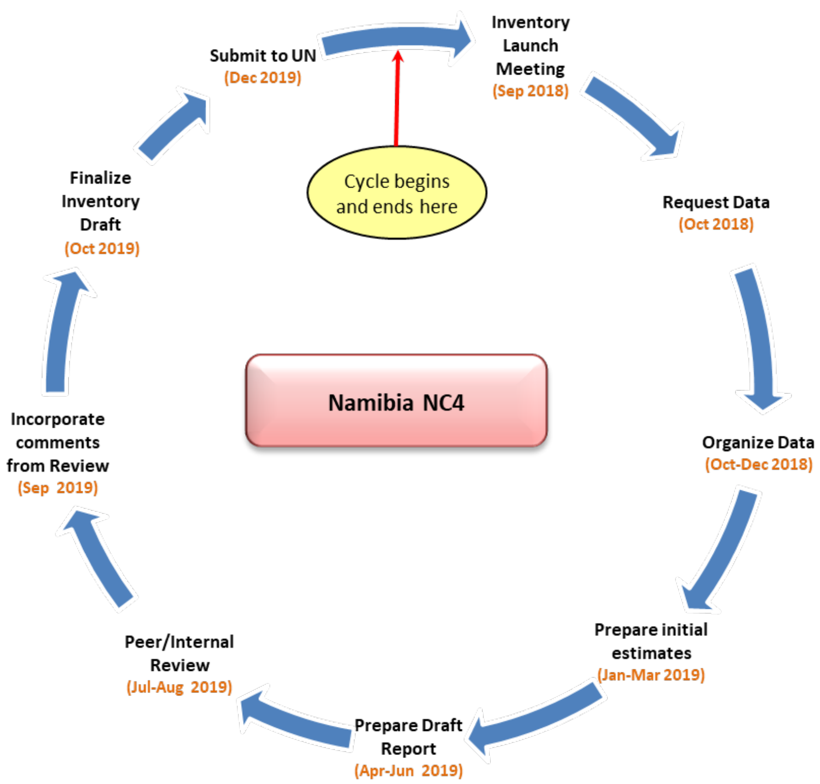


Figure 3.1 - The inventory cycle of Namibia's NC4

This seventh GHG inventory is presented as a chapter of the NC4 in lieu of a stand-alone national inventory report and provides data on GHG emissions by sources and removals by sinks for a full time series for the period 1991 to 2015, the years 1991 to 1993 and 2015 being additions to the previous one. Improvements over the previous inventory consisted in the inclusion of categories Medical Application of N_20, Refrigeration and Air Conditioning (RAC) and Harvested Wood Products (HWP). Once again, a mix of Tiers 1 and 2 has been adopted.

3.1.2. Institutional arrangements and inventory preparation

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

The CCU of MET 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 emission factors and enable moving to Tier 2 were consolidated. Capacity building of the inventory working group members continued.

The responsibilities within the institutional arrangements did not change with:

- The CCU of MET for inventory coordination, compilation and submission;
- Ministry of Mines and Energy for the Energy sector;
- Ministry of Industrialization, Trade and SME Development for the IPPU sector;
- Ministry of Agriculture, Water Affairs and Forestry for the AFOLU sector;
- MET for the Waste sector;
- Namibia NSA for Archiving, including provision of quality-controlled activity data;
- The CCU of MET for coordinating QA/QC;
- External consultant for capacity building and QA;
- The CCU of MET for coordinating Uncertainty Analysis; and
- The CCU of MET to act as GHG inventory specialist to track capacity building needs, the IPCC process and COP decisions for implementation.

The institutional arrangements for the compilation of the inventory and reporting for the different sectors are shown in Figure 3.2.

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 activity data;
- Selection of Tier level within each category and sub-category;
- Selection of emission factors (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 report for inclusion in NC4; and
- Submission to UNFCCC as a component of the NC4

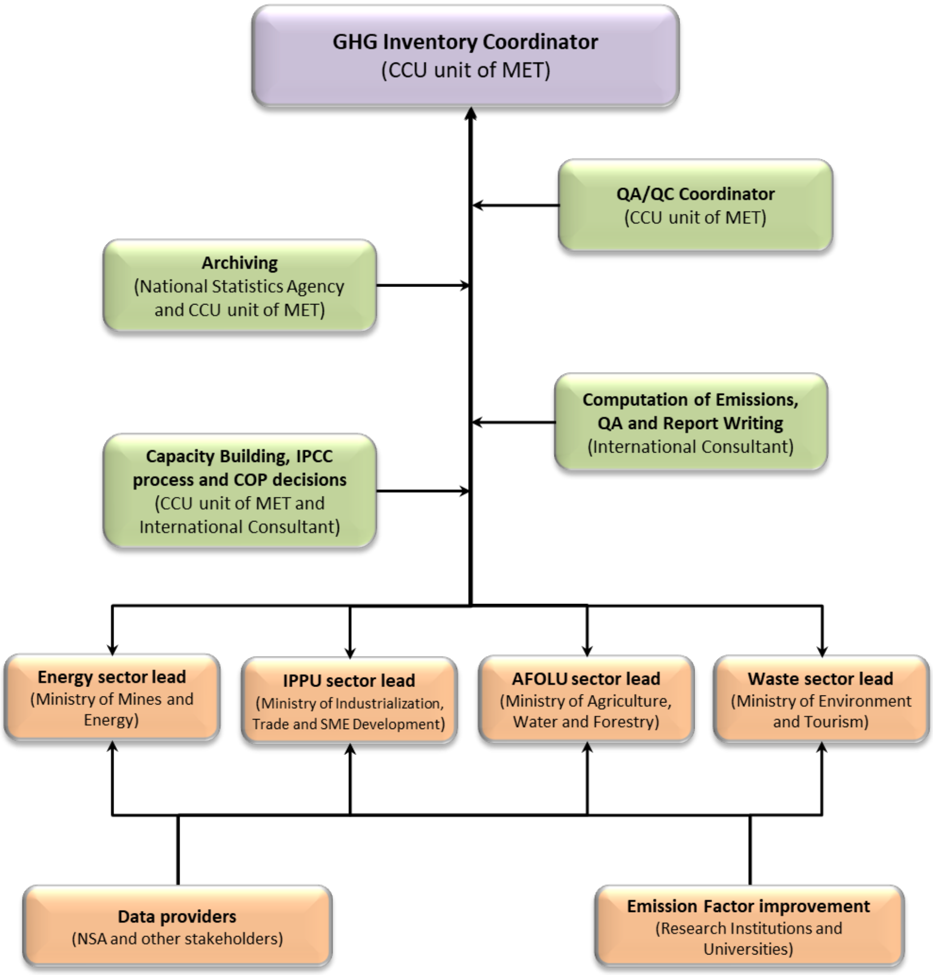


Figure 3.2 - Institutional arrangements for the GHG inventory preparation

3.1.3. 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. 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 with FOLU was performed using the tool available within the IPCC 2006 Software for both the level and trend assessments while the same exercise without FOLU was done using the EXCEL workbook. The results, with and without FOLU, for the level assessment for the year 2015 are presented in Table 3.1 and the trend assessment in Table 3.2.

Table 3.1 - Key Category Analysis for the year 2015 with and without FOLU- 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
With FOLU						
3.B.1.a	Forest land Remaining Forest land	CO_2	-120,525.8	120,525.8	0.844	0.844
3.B.3.b	Land Converted to Grassland	CO_2	9,755.9	9,755.9	0.068	0.913
3.A.1	Enteric Fermentation	CH_4	3,553.1	3,553.1	0.025	0.937
1.A.3.b	Road Transportation	CO_2	2,687.8	2,687.8	0.019	0.956
3.C.4	Direct N_2O Emissions from managed soils	N_2O	1,779.9	1,779.9	0.0132	0.969
3.C.1	Emissions from biomass burning	CH_4	966.3	966.3	0.007	0.976
Without FOLU						
3.A.1	Enteric Fermentation	CH_4	3,553.1	3553.1	0.309	0.309
1.A.3.b	Road Transportation	CO_2	2,687.8	2687.8	0.234	0.542
3.C.4	Direct N2O Emissions from managed soils	N_2O	1,779.9	1779.9	0.155	0.697
3.C.1	Emissions from biomass burning	CH_4	966.3	966.3	0.084	0.780
3.C.1	Emissions from biomass burning	N_2O	421.2	421.2	0.037	0.817
1.A.4	Other Sectors - Liquid Fuels	CO_2	375.3	375.3	0.033	0.850
2.A.1	Cement production	CO_2	330.2	330.2	0.029	0.879
2.C.6	Zinc Production	CO_2	141.0	141.0	0.012	0.891
3.A.2	Manure Management	N_2O	137.1	137.1	0.012	0.903
3.C.6	Indirect N2O Emissions from manure management	N_2O	125.6	125.6	0.011	0.914
2.F.1	Refrigeration and Air Conditioning	HFCs, PFCs	113.2	113.2	0.010	0.924
1.A.5	Non-Specified - Liquid Fuels	CO_2	106.9	106.9	0.009	0.933
1.A.2	Manufacturing Industries and Construction - Solid Fuels	CO_2	90.5	90.5	0.008	0.941
3.D.1	Harvested Wood Products	CO_2	-86.5	86.5	0.008	0.948
3.A.2	Manure Management	CH_4	84.7	84.7	0.007	0.955
4.A	Solid Waste Disposal	CH_4	84.2	84.2	0.007	0.963
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	CO_2	65.1	65.1	0.006	0.969
1.A.3.c	Railways	CO_2	48.7	48.7	0.004	0.973

There are four key categories in the quantitative level assessment when including FOLU for the year 2015, three of these from the AFOLU sector, namely enteric fermentation, Forest land Remaining Forest land and Road Transportation. When considering the KCA without FOLU, there is a sharp increase from four to fifteen. This is because the FOLU categories were the highest sinks and emitters, contributing to 91.3 % at absolute level in the KCA. When these two categories are not considered without FOLU, the contribution came from 11 categories to equal the same emissions/sinks at absolute level. It is important to point out that 11 out of the 15 key categories when considering the analysis without FOLU contributed less than 2% individually. This raises the question of whether it is worth prioritising these categories for Tier 2 level estimation of emissions and also within the national mitigation strategy.

The results change quite drastically when considering the trend assessment covering the period 1991 to 2015 (Table 3.2). There are now twelve and eleven key categories when considering the assessment without FOLU, with four categories contributing less than 2% of national emissions under both situation with and without FOLU.

Table 3.2 - Key Category Analysis for the period 1991 - 2015 - 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
With FOLU							
3.B.1.a	Forest land Remaining Forest land	CO_2	-93,467.7	-120,525.8	0.035	0.234	0.234
3.B.3.b	Land Converted to Grassland	CO_2	8,671.9	9,755.9	0.035	0.231	0.465
1.A.3.b	Road Transportation	CO_2	570.1	2,687.8	0.020	0.134	0.599
3.A.1	Enteric Fermentation	CH_4	3,029.8	3,553.1	0.013	0.089	0.689
3.C.1	Emissions from Biomass Burning	CH_4	3,427.3	966.3	0.012	0.077	0.766
3.B.1.b	Land Converted to Forestland	CO_2	-1,619.9	-962.71	0.010	0.070	0.835
3.C.4	Direct N2O Emissions from Managed Soils	N_2O	1,510.9	1,779.9	0.006	0.045	0.880
3.C.1	Emissions from Biomass Burning	N_2O	1,501.9	412.2	0.005	0.034	0.914
2.A.1	Cement Production	CO_2	0	330.2	0.003	0.019	0.933
2.C.6	Zinc Production	CO_2	0	141.1	0.001	0.008	0.941
1.A.4	Other Sectors - Liquid Fuels	CO_2	375.9	375.3	0.001	0.007	0.949
2.F.1	Refrigeration and Air Conditioning	HFCs, PFCs	0	113.2	0.001	0.007	0.955
1.A.5	Non-Specified – Liquid Fuels	CO_2	9.13	106.9	0.001	0.006	0.961
3.D.1	Harvested Wood Products	CO_2	0	-86.5	0.001	0.005	0.966
3.C.6	Solid Waste Disposal	CH_4	10.9	84.2	0.001	0.004	0.970
Without FOLU							
3.C.1	Emissions from biomass burning	CH_4	3,427.3	966.3	0.338	0.334	0.338
1.A.3.b	Road Transportation	CO_2	570.1	2,687.8	0.277	0.277	0.615
3.C.1	Emissions from biomass burning	N_2O	1,501.9	421.2	0.148	0.148	0.763
3.A.1	Enteric Fermentation	CH_4	3,029.8	3,553.1	0.057	0.057	0.820
2.A.1	Cement production	CO_2	0	330.2	0.044	0.044	0.864
3.C.4	Direct N2O Emissions from managed soils	N_2O	1510.9	1779.9	0.030	0.030	0.894
2.C.6	Zinc Production	CO_2	0	141.0	0.019	0.019	0.912
2.F.1	Refrigeration and Air Conditioning	HFCs , PFCs	0	113.2	0.015	0.015	0.927
1.A.5	Non-Specified - Liquid Fuels	CO_2	9.1	106.9	0.013	0.015	0.940
3.D.1	Harvested Wood Products	CO_2	0	-86.5	0.011	0.011	0.951
4.A	Solid Waste Disposal	CH_4	10.9	84.2	0.010	0.009	0.960
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	CO_2	29.4	65.1	0.005	0.006	0.966
1.A.3.b	Road Transportation	N_2O	8.5	41.6	0.004	0.004	0.970
3.A.2	Manure Management	N_2O	106.8	137.1	0.004	0.004	0.974

The summary of Key Categories based on the quantitative trend and level assessments to the 95% with FOLU is presented in Table 3.3.

Table 3.3 - Summary of Key Categories for level (2015) and trend (1991 to 2015) assessments

Number	IPCC category code	IPCC category	GHG	Identification criteria	Comment
1	3B1a	Forest land Remaining Forest land	CO_2	L1, T1	Quantitative
2	3B3b	Land Converted to Grassland	CO_2	L1, T1	Quantitative
3	3A1	Enteric fermentation	CH_4	L1, T1	Quantitative
4	1A3b	Road Transportation	CO_2	L1, T1	Quantitative
5	3B1b	Land Converted to Forest land	CO_2	T1	Quantitative
6	3C1	Emissions from Biomass Burning	CH_4	T1	Quantitative
7	3C4	Direct Emissions from Managed soils	N_2O	T1	Quantitative
8	3C1	Emissions from Biomass Burning	N_2O	T1	Quantitative
9	2A1	Cement Production	CO_2	T1	Quantitative
10	2C6	Zinc Production	CO_2	T1	Quantitative
11	1.A.4	Other Sectors - Liquid Fuels	CO_2	T1	Quantitative
12	2.F.1	Refrigeration and Air Conditioning	HFCs, PFCs	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.

3.1.4. Methodological issues

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.

As the IPCC 2006 Guidelines do not fully address compilations at the Tier 2 level, national emission factors and stock factors as appropriate have been derived and adopted to compile estimates at the Tier 2 level partially for the Livestock and Land sectors. This is good practice and improved the accuracy of the emission estimates and reduced the uncertainty level.

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 those from the IPCC Second Assessment Report for the three direct GHGs, namely carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) as well as for the gases used for Refrigeration and Air Conditioning (Table 3.4). Additional gases, known as (indirect gases), which affect global warming, namely oxides of nitrogen (NO_x), carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs) and sulphur dioxide (SO_2), have also been computed and reported in the inventory.

Table 3.4 - Global Warming Potential

Gas		Global Warming Potential
Carbon Dioxide	(CO_2)	1
Methane	(CH_4)	21
Nitrous Oxide	(N_2O)	310
HFC - 32	(CH2F2)	650
HFC - 125	(CH2CF3)	2800
HFC – 134a	(CF2FCF3)	1300
HFC – 143a	(CF3CH3)	3800

Default EFs were assessed for their appropriateness prior to their adoption, 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 Tier levels, were sourced directly from both public and private sector operators. Data gaps were filled through personal contacts with the stakeholders and/or from results of surveys, scientific studies and by statistical modelling. 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.

3.1.5. Quality Assurance and Quality Control (QA/QC)

Namibia has its own national system for quality control (QC) of data being collected within the different institutions. All data are quality controlled at different stages of the process until the final quality assurance (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.

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

- Confirm data quality and reliability 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 MRV system under development. Thus, systematic records as per the *2006 IPCC Guidelines* still has to be developed under a dedicated QA/QC coordinator. This resulted from the lack of permanent personnel on the establishment, insufficient capacity and since 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, listed below with actions taken, are:

- Use of N_2O for medical applications and ODS are now covered while incineration of medical waste is still being implemented;
- Institutional arrangements to ensure annual provision of AD for preparing the inventory are in the implementation phase;
- Develop and implement a QC management system remains a problem due to lack of permanent staff;
- Improve 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 under way.

3.1.6. Uncertainty assessment

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 values 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 used. 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 recommended methodology, the uncertainty level was derived according to the procedure proposed in the IPCC Guidelines and used in the uncertainty analysis. The uncertainty analysis has been performed using the tool available within the IPCC 2006 Software. Uncertainties in total emissions based on the IPCC tool including emissions and removals from the Land sector is presented in Table 3.5. Uncertainty levels for the individual years of the period 1991 to 2015 varied from 26.7% to 29.1% while the trend assessment when adding one successive year on the base year 1991 for the years 1991 to 2015 ranged from 35.8% to 45.8%.

Table 3.5 - Overall uncertainty (%)

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Annual	28.2	28.0	27.8	27.7	27.6	27.3	27.2	27.1	27.0	27.0	27.1	26.9	26.8
Trend (base year 1991)	-	35.8	36.0	36.2	36.9	37.6	38.2	39.0	39.7	40.5	40.6	42.3	42.5

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Annual	26.7	26.9	27.4	27.8	26.9	28.2	27.7	28.7	29.1	26.8	27.3	27.2
Trend (base year 1994)	43.1	42.3	40.9	39.9	43.2	38.7	40.3	39.8	39.4	46.2	45.1	45.8

3.1.7. 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.

3.1.8. Recalculations

There have been no recalculations performed during the computation of the present inventory. Recalculated emissions for the base years 1994, 2000 and 2010 are reproduced in Table 3.6 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 present inventory and default EFs while recalculated values are compiled in line with 2006 IPCC GL, new improved data sets, a mix of Tiers 1 and 2, the latter for most key categories and an wider coverage.

Table 3.6 - Comparison of original and recalculated emissions, removals and net removals of past inventories presented in national communications

Year	1994		2000		2010	
	INC	NC4	SNC	NC4	TNC	NC4
Removals	-5,716	-96,659	-10,566	-108,117	-28,534	-107,450
Emissions	5,685	18,898	9,118	18,671	27,195	20,726
Net removals	-31	-77,761	-1,442	-89,426	-1,339	-86,725

3.1.9. Time series consistency

This inventory now covers the period 1991 to 2015 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 the emissions.

3.1.10. Gaps, constraints and needs

Namibia, as a NAI country, still faces serious challenges to report to the required standards to the Convention, including the inventory component. In order to reduce uncertainties and aim at producing an inventory in line with TACCC principles, Namibia invested in improving its national GHGIMS and Institutional arrangements. One major challenge for estimating emissions for the past years from 1991 to 1999 was gaps in AD. The latter were not readily available since the country was still setting up its national statistics department after 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 2015.

For this inventory, three more categories, namely N_2O for Medical Applications, RAC, and Harvested Wood Products (HWP) have been included. Some information has also been collected on the use of SF_6, and incineration of medical wastes, but unfortunately, they were not detailed enough to enable computation of emissions in these categories. The following major problems were encountered during the preparation of this national inventory of GHG:

- Almost all 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 sectors and categories are not readily available and had to be generated based on scientific and consumption parameters;
- Lack of solid waste characterization data, amount generated, and wastewater generated from the industrial sector were only partly available;
- National experts could not take over the full inventory compilation process because of insufficient time available when considering their other responsibilities.

3.1.11. 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 most urgent improvements has been made. These are: Adequate and proper data capture, QC, Validation, Storage and retrieval mechanism needed to facilitate the compilation of future inventories; Capacity building and strengthening of the existing institutional framework within a GHGIMS to provide improved coordination for a smooth implementation of the GHG inventory cycle for sustainable production of inventories; Development of emission factors (EFs) more representative of the national context; Improved existing QA/QC system including a QA/QC plan in order to reduce uncertainty and improve inventory quality; Find the necessary financial resources to establish a GHG inventory unit within DEA to be responsible for inventory compilation and coordination; Institutionalize the archiving system; Pursue efforts 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 developed with the new approach adopted for the Land sector; Produce new maps for 1990 to 2015 to refine land use change data over 5 years periods to replace the poor-quality maps available now; Refine data collection for determining country-specific (CS) weights for dairy cows, other cattle, sheep and goats; Develop the digestible energy (DE) factor for livestock as country-specific data is better than the default IPCC value to address this key category fully at Tier 2; and Add the missing year 1990 to complete the full time series 1990 to the latest year for compliance in inventory compilation. These improvements will be addressed during the preparation of the NIR4 within the framework of the BUR4.

3.2 Trends in greenhouse gas emissions

3.2.1. The period 1991 to 2015

Namibia remained a net GHG sink over the period 1991 to 2015 as the Land category removals exceeded emissions from the other categories. The net removal of CO_2 increased by 25,258 Gg from 75,239 Gg to 100,497 Gg in 2015, representing an increase of 33.6% over these 25 years. During the same period, the country recorded an increase of 6.2% in emissions, from 19,849 Gg CO_2-eq to 21,554 Gg CO_2-eq. The trend for the period 1991 to 2015 indicates that the total removals from the LAND category increased from 95,088 Gg CO_2-eq in 1991 to 121,575 Gg CO_2-eq in 2015 (Table 3.7 and Figure 3.3).

Table 3.7 - GHG emissions (Gg CO_2-eq) characteristics (1991 - 2015)

Year	Total emissions	AFOLU removals	Net	Per capita emission (t)	GDP emissions index (Year 1991 = 100)
1991	19,849	95,088	75,239	13.3	100.0
1992	19,469	95,643	76,174	12.8	98.1
1993	19,049	96,151	77,102	12.3	96.0
1994	18,898	96,659	77,761	11.9	95.2
1995	18,762	98,466	79,705	11.6	90.8
1996	18,447	100,291	81,844	11.2	86.5
1997	18,450	102,133	83,683	10.9	83.0
1998	18,502	104,175	85,672	10.8	80.6
1999	18,560	106,068	87,508	10.6	78.2
2000	18,691	108,117	89,426	10.4	76.1
2001	19,164	108,388	89,224	10.5	77.1
2002	18,399	112,687	94,287	9.9	70.6
2003	18,848	113,171	94,323	10.0	69.4
2004	18,748	114,970	96,222	9.8	61.5
2005	19,141	112,769	93,628	9.9	61.3
2006	20,200	109,173	88,973	10.3	60.4
2007	20,730	106,421	85,690	10.4	58.8
2008	19,422	115,035	95,613	9.6	53.3
2009	21,554	103,277	81,723	10.5	59.8
2010	20,726	107,450	86,725	10.0	54.1
2011	22,705	105,570	82,866	10.8	56.0
2012	23,548	104,576	81,028	11.0	55.3
2013	19,835	122,439	102,604	9.2	44.1
2014	21,186	119,525	98,340	9.6	44.3
2015	21,078	121,575	100,497	9.5	44.1

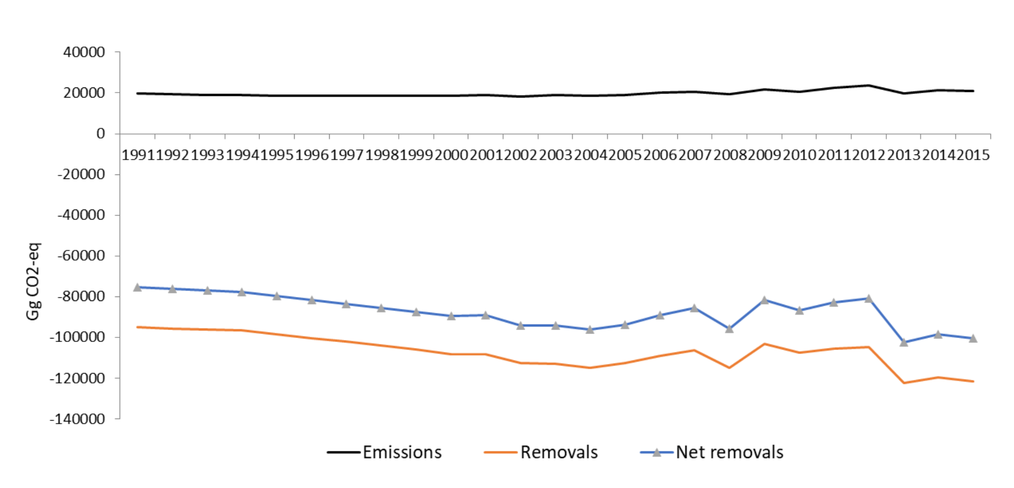


Figure 3.3 - Evolution of national emissions, national removals and the overall (net) situation (Gg CO_2-eq), (1991 – 2015)

Per capita emissions of GHG decreased gradually from 13.3 tonnes CO_2-eq in 1991 to reach 9.9 tonnes in 2002; it then plateaued between 9.8 and 10.0 tonnes up to 2005 after which period it seesawed to reach 9.5 tonnes CO_2-eq in 2015 (Figure 3.4). The GDP emission index decreased almost steadily from 100 in the year 1991 to 44 in 2015 (Figure 3.5).

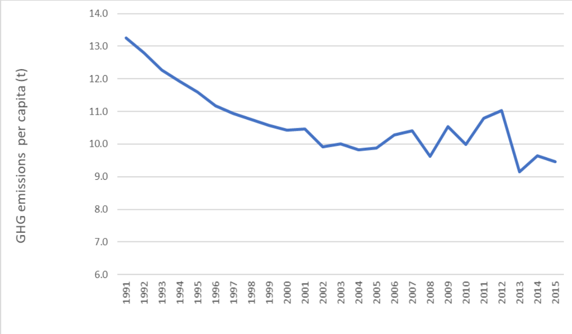


Figure 3.4 - Per capita GHG emissions (1991 - 2015)

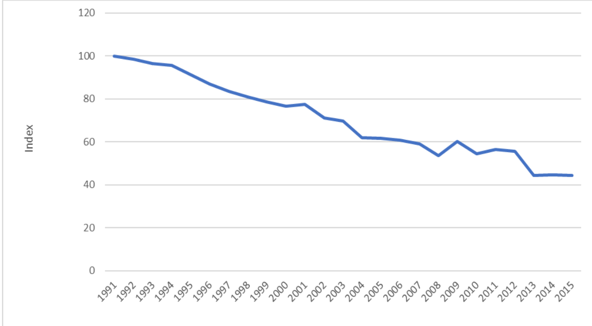


Figure 3.5 - GDP emissions index (1991 - 2015)

3.2.2. Trend of emissions by sector

Total national emissions increased by 6.2% over these 25 years. 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 2003. Emissions from the AFOLU sector decreased from 18,574 Gg CO_2-eq in 1991 to 16,856 in 2015, representing a decrease of 9% from the 1991 level. The share of GHG emissions from the AFOLU sector out of total national emissions regressed from 93.5% in 1991 to 80.0% in 2015.

Energy emissions increased from 1,177 Gg CO_2-eq (6.0%) of national emissions in 1991 to 3,541 Gg CO_2-eq (16.8%) in 2015 as depicted in Table 3.8. During the period 1991 to 2015, the emissions increased by three times.

The contribution of the IPPU sector in total national emissions increased from 21 Gg CO_2-eq in 1991 to 518 Gg CO_2-eq in 2015 (Table 3.8). 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 varied slightly over this period with the tendency being for a slight increase over time. Emissions from the waste sector increased from the 1991 level of 76 Gg CO_2-eq to 163 Gg CO_2-eq in 2015, representing a 115% increase.

In 2015, Energy contributed 16.8% of emissions, IPPU 2.5%, AFOLU 80.0% and Waste 0.8%.

Table 3.8 - National GHG emissions (Gg, CO_2-eq) by sector (1991 - 2015)

Year	Total emissions	Energy	IPPU	AFOLU	Waste
1991	19,849	1,177	21	18,574	76
1992	19,469	1,252	22	18,117	79
1993	19,049	1,350	23	17,595	81
1994	18,898	1,464	23	17,328	83
1995	18,762	1,473	24	17,183	81
1996	18,447	1,566	24	16,777	80
1997	18,450	1,617	25	16,726	82
1998	18,502	1,759	26	16,633	85
1999	18,560	1,893	26	16,551	89
2000	18,691	1,934	26	16,637	94
2001	19,164	2,116	26	16,927	95
2002	18,399	2,163	28	16,112	96
2003	18,848	2,454	112	16,176	106
2004	18,748	2,521	239	15,879	108
2005	19,141	2,671	262	16,094	114

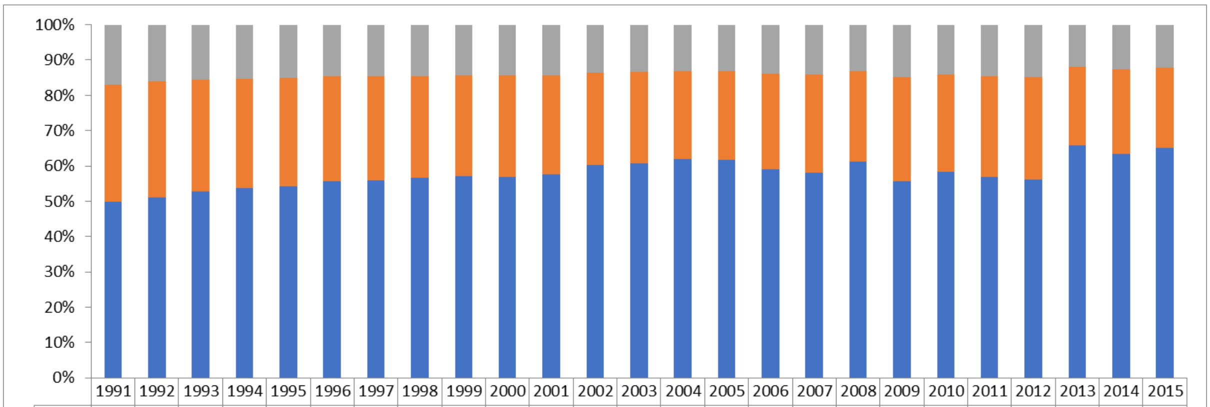
Year	Total emissions	Energy	IPPU	AFOLU	Waste
2006	20,200	2,823	257	17,003	116
2007	20,730	2,907	295	17,415	113
2008	19,422	2,752	293	16,256	121
2009	21,554	2,832	305	18,289	129
2010	20,726	2,923	303	17,365	135
2011	22,705	2,796	440	19,326	142
2012	23,548	3,004	517	19,875	152
2013	19,835	2,862	530	16,291	152
2014	21,186	3,235	525	17,271	155
2015	21,078	3,541	518	16,856	163

3.2.3. Trend in emissions of direct GHGs

The share of emissions by gas did not change during the period 1991 to 2015. 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. In 2015, the share of the GHG emissions was as follows: 65.1% CO_2, 22.7% CH_4 and 12.2% N_2O. The trend of the aggregated emissions and removals by gas is given in Table 3.9 and Figure 3.6.

Table 3.9 - Aggregated emissions and removals (Gg) by gas (1991 - 2015)

Year	Total GHG emissions (CO_2-eq)	Removals (CO_2) (CO_2-eq)	Net removals (CO_2-eq)	CO_2	CH_4 (CO_2-eq)	N_2O (CO_2-eq)
1991	19,849	-95,088	-75,239	9,885	6,608	3,356
1992	19,469	-95,643	-76,174	9,959	6,372	3,138
1993	19,049	-96,151	-77,102	10,056	6,026	2,967
1994	18,898	-96,659	-77,761	10,169	5,844	2,884
1995	18,762	-98,466	-79,705	10,177	5,735	2,850
1996	18,447	-100,291	-81,844	10,268	5,465	2,714
1997	18,450	-102,133	-83,683	10,318	5,421	2,711
1998	18,502	-104,175	-85,672	10,457	5,358	2,687
1999	18,560	-106,068	-87,508	10,591	5,301	2,668
2000	18,691	-108,117	-89,426	10,629	5,373	2,688
2001	19,164	-108,388	-89,224	11,021	5,399	2,744
2002	18,399	-112,687	-94,287	11,109	4,802	2,488
2003	18,848	-113,171	-94,323	11,438	4,878	2,532
2004	18,748	-114,970	-96,222	11,630	4,670	2,448
2005	19,141	-112,769	-93,628	11,799	4,837	2,506
2006	20,200	-109,173	-88,973	11,944	5,462	2,794
2007	20,730	-106,421	-85,690	12,063	5,720	2,947
2008	19,422	-115,035	-95,613	11,910	4,947	2,564
2009	21,554	-103,277	-81,723	11,999	6,366	3,189
2010	20,726	-107,450	-86,725	12,086	5,735	2,905
2011	22,705	-105,570	-82,866	12,922	6,480	3,302
2012	23,548	-104,576	-81,028	13,204	6,848	3,496
2013	19,835	-122,439	-102,604	13,076	4,398	2,362
2014	21,186	-119,525	-98,340	13,436	5,082	2,668
2015	21,078	-121,575	-100,497	13,730	4,780	2,567



	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
N2O	16.9	16.1	15.6	15.3	15.2	14.7	14.7	14.5	14.4	14.4	14.3	13.5	13.4	13.1	13.1	13.8	14.2	13.2	14.8	14	14.5	14.8	11.9	12.6	12.2
CH4	33.3	32.7	31.6	30.9	30.6	29.6	29.4	29	28.6	28.7	28.2	26.1	25.9	24.9	25.3	27	27.6	25.5	29.5	27.7	28.5	29.1	22.2	24	22.7
CO2	49.8	51.2	52.8	53.8	54.2	55.7	55.9	56.5	57.1	56.9	57.5	60.4	60.7	62	61.6	59.1	58.2	61.3	55.7	58.3	56.9	56.1	65.9	63.4	65.1

Figure 3.6 - Share of aggregated emissions (Gg CO_2-eq) by gas (1991 – 2015)

3.2.3.1. Carbon dioxide (CO_2)

The most significant anthropogenic GHG was CO_2. CO_2 emissions increased by 3,851 Gg from the 1991 level of 9,885 Gg (Table 3.9) to 13,736 Gg in 2015. In the same year, the sector that emitted the highest amount of CO_2 was AFOLU with 9,769 Gg followed by Energy with 3,443 Gg (Table 3.10).

Table 3.10 - CO_2 emissions (Gg) by source category (1991 - 2015)

Year	Total emissions	Total net removals	Energy	IPPU	AFOLU - emissions	AFOLU - removals	Waste
1991	9,885	-85,203	1,128	20	8,736	-95,088	0.9
1992	9,959	-85,684	1,201	21	8,736	-95,643	0.9
1093	10,056	-86,095	1,298	22	8,736	-96,151	0.9
1994	10,169	-86,490	1,410	22	8,736	-96,659	1.9
1995	10,177	-88,290	1,417	23	8,736	-98,466	1.0
1996	10,268	-90,023	1,508	23	8,736	-100,291	1.0
1997	10,318	-91,815	1,557	24	8,736	-102,133	1.1
1998	10,457	-93,717	1,696	24	8,736	-104,175	1.1
1999	10,591	-95,477	1,829	25	8,735	-106,068	1.2
2000	10,629	-97,487	1,868	25	8,736	-108,117	1.2
2001	11,021	-97,367	2,046	25	8,949	-108,388	1.3
2002	11,109	-101,578	2,093	27	8,949	-112,687	1.3
2003	11,438	-101,733	2,379	110	8,947	-113,171	1.4
2004	11,630	-103,341	2,444	237	8,947	-114,970	1.4
2005	11,799	-100,971	2,590	260	8,947	-112,769	1.5
2006	11,944	-97,229	2,740	255	8,947	-109,173	1.6
2007	12,063	-94,358	2,822	293	8,947	-106,421	1.7
2008	11,910	-103,125	2,671	291	8,946	-115,035	1.7
2009	11,999	-91,278	2,748	303	8,947	-103,277	1.8
2010	12,086	-95,365	2,837	301	8,947	-107,450	1.9
2011	12,922	-92,648	2,713	438	9,769	-105,570	2.1
2012	13,204	-91,372	2,918	515	9,769	-104,576	2.3
2013	13,076	-109,364	2,776	528	9,769	-122,439	2.3
2014	13,436	-106,089	3,142	522	9,769	-119,525	2.4
2015	13,730	-107,845	3,443	515	9,769	-121,575	2.4

3.2.3.2. Methane (CH_4)

Methane was the next contributor in national emissions after CO_2. It contributed 4,780 Gg CO_2-eq of the total emissions of 2015. Methane emissions decreased by 1828 Gg CO_2-eq from the 1991 level of 6,608 Gg CO_2-eq to 4,780 in 2015 (Table 3.11). AFOLU contributed between 96 to 99% of these emissions followed by the Waste sector.

Table 3.11 - CH_4 emissions (Gg) by source category (1991 - 2015)

Year	Total (Gg CO_2-eq)	Total	Energy	AFOLU - emissions	Waste
1991	6,608	315	1.4	311	2.5
1992	6,372	303	1.5	299	2.6
1993	6,026	287	1.5	283	2.7
1994	5,837	278	1.5	274	2.8
1995	5,728	273	1.5	269	2.7
1996	5,458	260	1.6	256	2.6
1997	5,415	258	1.6	254	2.7
1998	5,352	255	1.6	251	2.8
1999	5,295	252	1.7	248	3.0
2000	5,367	256	1.7	251	3.2
2001	5,394	257	1.7	252	3.3
2002	4,797	228	1.7	224	3.3
2003	4,873	232	1.8	227	3.8
2004	4,665	222	1.8	217	3.8
2005	4,832	230	1.8	224	4.1
2006	5,458	260	1.9	254	4.2
2007	5,717	272	1.9	267	4.0
2008	4,944	235	1.8	229	4.4
2009	6,362	303	1.9	297	4.7
2010	5,732	273	1.9	266	5.0
2011	6,477	308	1.8	301	5.3
2012	6,845	326	1.9	318	5.8
2013	4,395	209	1.8	202	5.9
2014	5,079	242	1.9	234	6.1
2015	4,780	228	2.0	219	6.4

3.2.3.3. Nitrous Oxide (N_2O)

Nitrous oxide emissions stood at 2,567 Gg CO_2-eq in 2015. Emissions regressed by 692 Gg CO_2-eq from 3,259 Gg CO_2-eq in the year 1991 to 2,567 Gg CO_2-eq (Table 3.12) in 2015. The AFOLU sector was the highest emitter of N_2O with some 98%.

Table 3.12 - N_2O emissions (Gg) by source category (1991 - 2015)

Year	Total emissions (Gg CO_2-eq)	Total	Energy	IPPU	AFOLU - emissions	Waste
1991	3,259.5	10.51	0.06	0.003	10.38	0.07
1992	3,138.3	10.12	0.06	0.003	9.98	0.07
1993	2,966.7	9.57	0.07	0.003	9.43	0.07
1994	2,883.6	9.30	0.07	0.003	9.15	0.08
1995	2,847.2	9.18	0.08	0.003	9.04	0.07
1996	2,713.1	8.75	0.08	0.004	8.59	0.08
1997	2,709.7	8.74	0.09	0.004	8.58	0.08
1998	2,685.3	8.66	0.09	0.004	8.49	0.08

Year	Total emissions (Gg CO_2-eq)	Total	Energy	IPPU	AFOLU - emissions	Waste
1999	2,666.8	8.60	0.10	0.004	8.43	0.08
2000	2,686.8	8.67	0.10	0.004	8.49	0.08
2001	2,742.2	8.85	0.11	0.005	8.66	0.08
2002	2,486.9	8.02	0.11	0.005	7.83	0.08
2003	2,530.7	8.16	0.12	0.005	7.96	0.08
2004	2,446.5	7.89	0.13	0.005	7.68	0.08
2005	2,504.1	8.08	0.13	0.005	7.86	0.09
2006	2,792.5	9.01	0.14	0.006	8.78	0.09
2007	2,944.8	9.50	0.15	0.006	9.26	0.09
2008	2,562.6	8.27	0.14	0.006	8.04	0.09
2009	3,187.1	10.28	0.14	0.006	10.05	0.09
2010	2,902.8	9.36	0.15	0.007	9.13	0.09
2011	3,300.3	10.65	0.14	0.007	10.41	0.09
2012	3,493.7	11.27	0.15	0.007	11.03	0.09
2013	2,359.1	7.61	0.15	0.007	7.37	0.09
2014	2,664.7	8.60	0.17	0.008	8.35	0.08
2015	2,567.4	8.28	0.18	0.008	8.01	0.08

3.2.4. Trends for indirect GHGS and SO_2

Emissions of indirect GHGs (CO, NO_x and NMVOC) and SO_2, have also been estimated and emissions of these gases for the period 1991 to 2015 are given in Table 3.13. Emissions of NO_x decreased from 50.5 Gg in the year 1991 to 38.4 Gg in 2015. CO emissions also regressed, from 2,547 Gg in 1994 to 939 Gg in 2015. Emissions of NMVOC increased from 16.0 Gg in 1991 to 24.7 Gg in 2015 whilst emissions of SO_2 varied between 1.9 Gg and 4.2 Gg during the same period.

Table 3.13 - Emissions (Gg) of indirect GHGs and SO_2 (1991 - 2015)

Year	NO_x	CO	NMVOC	SO_2
1991	50.5	2,547.3	16.0	2.0
1992	49.4	2,426.6	16.0	2.1
1993	48.7	2,313.0	15.7	2.4
1994	48.4	2,198.6	16.0	2.6
1995	45.0	2,083.2	16.1	2.1
1996	43.8	1,966.9	16.3	2.2
1997	41.4	1,849.6	16.8	1.9
1998	41.4	1,731.4	17.7	2.3
1999	41.1	1,612.3	18.4	2.5
2000	39.0	1,465.7	19.8	2.2
2001	40.6	1,479.0	19.8	2.4
2002	37.0	1,133.0	19.4	2.7
2003	38.8	1,140.7	20.2	3.0
2004	36.9	1,024.8	20.6	3.5
2005	41.1	1,267.3	20.4	3.7
2006	45.5	1,618.8	21.4	4.2
2007	49.3	1,904.4	21.5	4.0
2008	37.0	1,200.4	21.4	4.1
2009	54.9	2,263.2	21.8	3.7

Year	NO_x	CO	NMVOC	SO_2
2010	51.2	1,946.0	21.9	3.0
2011	52.7	2,076.8	22.9	3.0
2012	56.3	2,166.1	24.0	3.7
2013	30.7	657.2	22.6	2.5
2014	38.2	939.1	24.7	2.7
2015	38.4	939.1	24.7	2.7

3.2.4.1. NO_x

Emissions of NO_x decreased by 24% over the inventory period from 50.5 Gg in the year 1991 to 38.4 Gg in 2015 (Table 3.14). The two main sources of NO_x emissions were the Energy and AFOLU sectors. The Energy sector witnessed an increase from 22% to 70% while the AFOLU sector contribution regressed from 78% to 29% of total national emissions from 1991 to 2015. Waste contributed the remainder.

Table 3.14 - NO_x emissions (Gg) by source category (1991 - 2015)

Year	Total emissions	Energy	AFOLU	Waste
1991	50.5	10.9	39.5	0.2
1992	49.4	11.7	37.5	0.2
1993	48.7	12.8	35.7	0.2
1994	48.4	14.3	33.8	0.2
1995	45.0	12.8	32.0	0.2
1996	43.8	13.4	30.1	0.2
1997	41.4	13.0	28.2	0.2
1998	41.4	14.8	26.3	0.2
1999	41.1	16.5	24.4	0.2
2000	39.0	16.7	22.1	0.2
2001	40.6	18.2	22.2	0.3
2002	37.0	19.9	16.8	0.3
2003	38.8	21.7	16.8	0.3
2004	36.9	21.7	14.9	0.3
2005	41.1	22.1	18.7	0.3
2006	45.5	21.1	24.1	0.3
2007	49.3	20.4	28.5	0.3
2008	37.0	19.0	17.6	0.4
2009	54.9	20.5	34.1	0.4
2010	51.2	21.8	29.1	0.4
2011	52.7	21.1	31.2	0.4
2012	56.3	23.3	32.5	0.5
2013	30.7	21.2	9.1	0.5
2014	38.2	24.4	13.3	0.5
2015	38.4	26.9	11.0	0.5

3.2.4.2. CO

The major contributor of CO was the AFOLU sector with between 89% and 98% of national emission followed by the Energy sector with between 2% to 10% (Table 3.15). National CO emissions decreased from 2,547 Gg in the year 1991 to 788 Gg in 2015. The AFOLU sector contributed 705 Gg of total CO emissions compared to 74 Gg by the Energy sector and 8.6 Gg by the Waste sector in 2015.

Table 3.15 - CO emissions (Gg) by source category (1991 - 2015)

Year	Total emissions	Energy	%Energy	AFOLU	%AFOLU	Waste	%Waste
1991	2,547.3	38.7	1.5%	2,505.4	98.4%	3.1	0.1%
1992	2,426.6	40.0	1.6%	2,383.3	98.2%	3.2	0.1%
1993	2,313.0	41.4	1.8%	2,268.3	98.1%	3.3	0.1%
1994	2,198.6	42.9	1.9%	2,152.3	97.9%	3.5	0.2%
1995	2,083.2	44.4	2.1%	2,035.2	97.7%	3.6	0.2%
1996	1,966.9	46.0	2.3%	1,917.2	97.5%	3.7	0.2%
1997	1,849.6	47.6	2.6%	1,798.1	97.2%	3.9	0.2%
1998	1,731.4	49.4	2.9%	1,678.0	96.9%	4.0	0.2%
1999	1,612.3	51.2	3.2%	1,556.9	96.6%	4.2	0.3%
2000	1,465.7	53.0	3.6%	1,408.3	96.1%	4.3	0.3%
2001	1,479.0	55.7	3.8%	1,418.8	95.9%	4.5	0.3%
2002	1,133.0	55.7	4.9%	1,072.6	94.7%	4.7	0.4%
2003	1,140.7	60.1	5.3%	1,075.7	94.3%	5.0	0.4%
2004	1,024.8	62.9	6.1%	956.7	93.4%	5.2	0.5%
2005	1,267.3	65.1	5.1%	1,196.7	94.4%	5.4	0.4%
2006	1,618.8	67.4	4.2%	1,545.7	95.5%	5.7	0.4%
2007	1,904.4	69.1	3.6%	1,829.3	96.1%	6.0	0.3%
2008	1,200.4	64.6	5.4%	1,129.5	94.1%	6.3	0.5%
2009	2,263.2	66.9	3.0%	2,189.8	96.8%	6.6	0.3%
2010	1,946.0	71.0	3.7%	1,868.1	96.0%	6.9	0.4%
2011	2,076.8	66.3	3.2%	2,003.0	96.4%	7.5	0.4%
2012	2,166.1	66.6	3.1%	2,091.2	96.5%	8.2	0.4%
2013	657.2	66.4	10.1%	582.4	88.6%	8.4	1.3%
2014	939.1	72.6	7.7%	858.0	91.4%	8.5	0.9%
2015	787.7	74.2	9.4%	704.9	89.5%	8.6	1.1%

3.2.4.3. NMVOCs

In 2015, NMVOCs emissions stood at 24.7 Gg compared to 16.0 Gg in the year 1991. The two main emission sources were the Energy and AFOLU sectors (Table 3.16). 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 3.16 - NMVOC emissions (Gg) by source category (1991 - 2015)

Year	Total emissions	Energy	IPPU	AFOLU	Waste
1991	16.0	5.4	0.5	10.0	0.1
1992	16.0	5.5	0.6	9.8	0.1
1993	15.7	5.7	0.6	9.2	0.1
1994	16.0	6.0	0.7	9.2	0.2
1995	16.1	6.1	0.7	9.1	0.2
1996	16.3	6.3	0.8	9.0	0.2
1997	16.8	6.5	0.9	9.3	0.2
1998	17.7	6.8	1.1	9.7	0.2
1999	18.4	7.0	1.2	10.0	0.2
2000	19.8	7.3	1.3	11.0	0.2
2001	19.8	7.1	1.5	10.9	0.2
2002	19.4	7.2	1.4	10.5	0.2
2003	20.2	7.7	1.6	10.6	0.3
2004	20.6	8.0	1.6	10.6	0.3

Year	Total emissions	Energy	IPPU	AFOLU	Waste
2005	20.4	8.3	1.7	10.1	0.3
2006	21.4	8.6	1.7	10.7	0.3
2007	21.5	8.8	1.8	10.5	0.3
2008	21.4	8.3	1.9	10.8	0.4
2009	21.8	8.6	2.1	10.7	0.4
2010	21.9	9.1	2.1	10.3	0.4
2011	22.9	8.6	2.2	11.7	0.5
2012	24.0	8.7	2.3	12.5	0.5
2013	22.6	8.4	2.3	11.3	0.5
2014	24.7	9.2	2.3	12.6	0.5
2015	24.7	9.5	2.4	12.2	0.6

3.2.4.4. SO_2

The energy sector remained nearly as the sole emitter of SO_2 (Table 3.17) during the full inventory period. Emissions fluctuated during the inventory period 1991 to 2015 from 1.9 Gg to 4.2 Gg. The Waste sector emitted an insignificant amount varying from 0.01 to 0.02 Gg during the inventory period.

Table 3.17 - SO_2 emissions (Gg) by source category (1991 - 2015)

Year	Total emissions	Energy	Waste
1991	2.0	2.0	0.01
1992	2.1	2.1	0.01
1993	2.4	2.4	0.01
1994	2.6	2.6	0.01
1995	2.1	2.1	0.01
1996	2.2	2.2	0.01
1997	1.9	1.9	0.01
1998	2.3	2.2	0.01
1999	2.5	2.5	0.01
2000	2.2	2.2	0.01
2001	2.4	2.4	0.01
2002	2.7	2.7	0.01
2003	3.0	3.0	0.01
2004	3.5	3.5	0.01
2005	3.7	3.7	0.01
2006	4.2	4.2	0.01
2007	4.0	4.0	0.01
2008	4.1	4.1	0.01
2009	3.7	3.7	0.01
2010	3.0	2.9	0.01
2011	3.0	3.0	0.01
2012	3.7	3.7	0.02
2013	2.5	2.5	0.02
2014	2.7	2.7	0.02
2015	2.9	2.8	0.02

Table 3.18 -Short Summary (Inventory Year 2015)

	Emissions (Gg)			Emissions CO2 Equivalents (Gg)				Emissions (Gg)				
Categories	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	-107844.961	227.634	8.286	113.162	NE	NE	NE	NE	35.337	777.745	22.715	2.714
1 - Energy	3443.029	1.955	0.183	NA	NA	NA	NA	NA	24.382	72.867	9.217	2.714
1.A - Fuel Combustion Activities	3443.029	1.955	0.183	NA	NA	NA	NA	NA	24.382	72.867	9.217	2.714
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	515.423	NO	0.012	113.162	NE	NE	NE	NE	NO	NO	1.035	NO
2.A - Mineral Industry	347.581	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	141.090	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.D - Non-Energy Products from Fuels and Solvent Use	26.752	NO	NO	NA	NA	NA	NA	NA	NO	NO	0.000	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	113.162	NE	NA	NA	NA	NA	NA	NA	NA
2.G - Other Product Manufacture and Use	NO	NO	0.012	NO	NE	NE	NO	NE	NA	NA	NA	NA
2.H - Other	0.000	0.000	NO	NA	NA	NA	NA	NA	0.000	0.000	1.035	0.000
3 - Agriculture, Forestry, and Other Land Use	-111805.813	219.242	8.008	NA	NA	NA	NA	NA	10.954	704.878	12.464	NO
3.A - Livestock	NA	173.227	0.442	NA	NA	NA	NA	NA	NA	NA	12.464	NA
3.B - Land	-111719.812	0.000	0.000	NA	NA	NA	NA	NA	NO	NO	NO	NO
3.C - Aggregate sources and non-CO2 emissions sources on land	0.470	46.014	7.566	NA	NA	NA	NA	NA	10.954	704.878	NA	NA
3.D - Other	-86.471	NO	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO

Categories	Emissions (Gg) Net CO2 (1)(2)	CH4	N2O	Emissions CO2 Equivalents (Gg) HFCs	PFCs	SF6	Other halogenated gases with CO2 equivalent conversion factors (3)	Other halogenated gases without CO2 equivalent conversion factors (4)	Emissions (Gg) NOx	CO	NMVOCs	SO2
4 - Waste	2.400	6.437	0.083	NA	NA	NA	NA	NA	0.000	0.000	0.000	0.000
4.A - Solid Waste Disposal	NA	4.009	NO	NA	NA	NA	NA	NA	NO	NO	0.000	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	2.400	1.005	0.013	NA	NA	NA	NA	NA	0.000	0.000	0.000	0.000
4.D - Wastewater Treatment and Discharge	NA	1.423	0.069	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 3.19 -Long Summary (Inventory Year 2015)

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	-107844.961	227.634	8.286	113.162	NE	NE	NE	NE	35.337	777.745	22.715	2.714
1 - Energy	3443.029	1.955	0.183	NA	NA	NA	NA	NA	24.382	72.867	9.217	2.714
1.A - Fuel Combustion Activities	3443.029	1.955	0.183	NA	NA	NA	NA	NA	24.382	72.867	9.217	2.714
1.A.1 - Energy Industries	20.602	0.000	0.000	NA	NA	NA	NA	NA	0.010	0.001	0.000	0.036
1.A.2 - Manufacturing Industries and Construction	178.308	0.034	0.005	NA	NA	NA	NA	NA	0.626	1.112	0.196	0.897
1.A.3 - Transport	2761.936	0.611	0.153	NA	NA	NA	NA	NA	16.328	51.215	5.408	0.025
1.A.4 - Other Sectors	375.278	1.303	0.019	NA	NA	NA	NA	NA	6.795	20.349	3.573	1.755
1.A.5 - Non-Specified	106.906	0.006	0.006	NA	NA	NA	NA	NA	0.623	0.190	0.040	0.000
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	515.423	NO	0.012	113.162	NE	NE	NE	NE	NO	NO	1.035	NO
2.A - Mineral Industry	347.581	NO	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.A.1 - Cement production	330.200	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.A.2 - Lime production	17.381	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	141.090	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	141.090	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
2.D - Non-Energy Products from Fuels and Solvent Use	26.752	NO	NO	NA	NA	NA	NA	NA	NO	NO	0.000	NO
2.D.1 - Lubricant Use	9.064	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.D.2 - Paraffin Wax Use	17.688	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	0.000	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	113.162	NE	NA	NA	NA	NA	NA	NA	NA
2.F.1 - Refrigeration and Air Conditioning	NA	NA	NA	113.162	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	0.012	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
2.G.3 - N2O from Product Uses	NA	NA	0.012	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	1.035	0.000

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.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	1.035	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	-111805.813	219.242	8.008	NA	NA	NA	NA	NA	10.954	704.878	12.464	NO
3.A - Livestock	NA	173.227	0.442	NA	NA	NA	NA	NA	NA	NA	12.464	NA
3.A.1 - Enteric Fermentation	NA	169.194	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.A.2 - Manure Management	NA	4.034	0.442	NA	NA	NA	NA	NA	NA	NA	12.464	NA
3.B - Land	-111719.812	NA	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO
3.B.1 - Forest land	-121488.522	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	0.470	46.014	7.566	NA	NA	NA	NA	NA	10.954	704.878	NA	NA
3.C.1 - Emissions from biomass burning	NA	46.014	1.359	NA	NA	NA	NA	NA	10.954	704.878	NA	NA
3.C.2 - Liming	NO	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.C.3 - Urea application	0.470	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.C.4 - Direct N2O Emissions from managed soils	NA	NA	5.742	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.C.5 - Indirect N2O Emissions from managed soils	NA	NA	0.060	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.C.6 - Indirect N2O Emissions from manure management	NA	NA	0.405	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.7 - Rice cultivations	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	-86.471	NO	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO
3.D.1 - Harvested Wood Products	-86.471	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	2.400	6.437	0.083	NA	NA	NA	NA	NA	0.000	0.000	0.000	0.000
4.A - Solid Waste Disposal	NA	4.009	NO	NA	NA	NA	NA	NA	NO	NO	0.000	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	2.400	1.005	0.013	NA	NA	NA	NA	NA	0.000	0.000	0.000	0.000
4.D - Wastewater Treatment and Discharge	NA	1.423	0.069	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

3.3 Energy

3.3.1. Description of 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.

3.3.1.1. Fuel Combustion Activities (1.A)

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 which stands at about 63% of Namibia's demand from the South African Power Pool (SAPP) compared to 65% in 2012. The fossil fuel generation plants are mainly used to supplement the imports and hydro production during peak demand time.

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.

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 modes of transport. Fuel supplied for international bunkering was also covered.

Other Sectors (1.A.4)

The sub-categories included under Other Sectors were the two main GHG contributors 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 really no underestimation in the inventory.

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.

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.

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.

3.3.2. 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 source categories. Thereafter, the IPCC conversion and emission factors were adopted to compile GHG emissions. The Sectoral approach covered all the IPCC source categories where AD were available.

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

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

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.

3.3.3. Activity Data

AD for the reference approach was obtained from the 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 United Nations database and the Food and Agriculture Organisation among others. These sources provided most of the AD required for the period 1991 to 2002 but to a lesser extent for the period 2003 to 2014 as the country was still in the process of organising its statistical organisation after gaining independence. Missing data for these years were thus obtained from the international databases or by 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 used for the inventory is given in Table 3.20.

Table 3.20 - 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.

Category	Fuel type	Data source
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.
	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 all categories. This is because the country is still in the process of putting in place its GHGIMS. 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 categories 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 Table 3.21.

3.3.4. 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 3.22.

3.3.5. Emission estimates

3.3.5.1. Reference approach

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

The results differed across the years between the two approaches with higher emissions for the reference approach for all years as expected. The difference was on the high side for some years, namely 1995, 1996, 1997 and 2001 with some 27% and for 2008 with 24% (Table 3.23) The wide differences between the two approaches possibly occurred as import-export data on fuels were not available prior to 2003 when the statistics system was being set-up. Another impacting factor would be 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 3.21 - Activity data (tonnes) used for Energy Sector

Categories	Type of fuel	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
Energy generation	HFO and LFO	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
	Bitum. coal	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
Mining	Gasoline	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
	Gasoil/Diesel	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
	Bitum. coal	29203	29518	29834	30150	30465	30781	31097	31413	31728	33479	39040	25800	38040	38040	32600	32840	28400	23960	31160	36160	49640	36148	36464	36780	37096
	Waste oil	427	427	427	427	427	427	427	427	427	483	224	618	1011	2050	3089	3483	5599	7440	7702	6948	7602	7615	7840	7686	7686
	Other petroleum pdts	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
	Petroleum coke	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
Other manufacturing	Gasoline	161.74	166.19	170.65	175	180	184	188	193	206	218	212	221	223	239	231	232	239	226	253	257	259	271	275	269	276
	Gasoil/Diesel	204.22	215.5	226.77	238	249	261	272	283	296	317	326	387	371	396	395	404	398	408	421	440	405	483	493	475	484
	Wood/wood waste	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27	30	27	27
Civil aviation	Aviation Gasoline	2595.7	2634.6	2673.5	2712	2751	2790	2829	2868	2907	3012	3043	3074	3105	3136	3167	3210	3210	3210	3210	3596	3413	3452	3491	3530	3568
	Jet kerosene	2429.6	2501.2	2572.8	2644	2716	2788	2859	2931	3002	3074	3105	3136	3168	3200	3232	3264	3297	3330	3363	3456	5652	4554	4554	4554	4554
Road transportation	Gasoline	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
	Diesel	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
	LPG	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	72	276	496	715	500	500	500	500	500
	Lubricant	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
Railways	Gasoil/Diesel	9862.5	10243	10623	11003	11383	11763	12143	12524	12904	12900	13607	14314	15021	15728	16435	16808	17207	16022	15710	6571	5948	6416	-	-	-
	Fuel oil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9857	8922	9624	14944	15570	15570
Residential	Other Kerosene	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
	LPG	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

Categories	Type of fuel	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
	Parafin wax	24000.0	24000.0	24000.0	24000	24000	24000	24000	24000	24000	23532	21855	23661	24265	27354	24612	23256	23303	27700	28791	22023	24000	24000	24000	24000	24000.0
	Wood fuel	239012	241004	243008	245023	247050	249088	251139	253202	255278	257368	259471	259685	259883	260063	260225	260369	260496	260605	260696	260769	260823	259319	257895	256551	255351
	Charcoal	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
Fishing	Gasoline	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
	Gasoil/Diesel	85014	90101	99547	112626	85741	85741	71935	87921	101000	98000	107000	128000	132000	121000	116000	90748	71932	65660	75460	78596	76636	93100	66836	81340	81400
Non-specified	Gasoline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	241	273	281	325	578
	Diesel	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
International aviation	Jet kerosene	20767	21533	22300	23066	23833	24599	25366	26132	26899	27665	27945	28227	28512	28800	29088	29379	29673	29969	30269	31120	37826	34473	34473	34473	34473
International marine bunkers	Gasoil/Diesel	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
	Gasoline	632	627	623	618	613	608	603	598	593	588	597	605	613	621	629	637	645	654	662	670	686	686	686	686	686
	Residual Fuel Oil	14795	14945	15096	15248	15402	15558	15715	15874	16034	16196	17399	18602	19805	21008	22211	23413	24616	25819	27022	28225	29428	29428	29428	29428	29428

Table 3.22 - List of emission factors (kg/TJ) used in the Energy sector

Fuel	CO_2	CH_4	N_2O	Emission factor CO_2	Emission factor CH_4	Emission factor 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

Table 3.23 - Comparison of the Reference and Sectoral Approaches (Gg CO_2) (1991 - 2015)

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Reference approach (Gg)	1247.7	1346.5	1383.6	1517.0	1806.4	1917.9	1964.5	2021.5	2035.6	2055.0	2606.9	2492.5	2680.4
Sectoral approach (Gg)	1128.0	1201.4	1297.7	1409.8	1417.5	1507.9	1557.2	1696.3	1829.0	1867.5	2045.9	2092.8	2378.9
Differences (%)	10.6	12.1	6.6	7.6	27.4	27.2	26.2	19.2	11.3	10.0	27.4	19.1	12.7

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Reference approach (Gg)	2837.9	2801.8	2916.2	3266.1	3297.9	3261.0	2912.1	2912.5	3408.6	3028.1	3189.1	3727.1
Sectoral approach (Gg)	2443.8	2590.3	2740.3	2821.7	2670.8	2748.3	2836.6	2713.1	2917.6	2775.9	3142.3	3443.0
Differences (%)	16.1	8.2	6.4	15.7	23.5	18.7	2.7	7.3	16.8	9.1	1.5	8.2

3.3.5.2. Sectoral approach

Total aggregated emissions for the three direct GHGs are provided in Table 3.24 while the share of emissions by category is depicted in Figure 3.7 for the five IPCC sub-categories falling under Fuel Combustion activities for the time series 1991 to 2015. Total emissions from Fuel Combustion Activities varied from 1,177.1 Gg CO_2-eq in 1991 to 3,540.0 Gg CO_2-eq in 2015. The emissions varied between the years under review as fuel combustion is related to economic activity and other factors.

Table 3.24 - Emissions for Fuel Combustion Activities (Gg CO_2-eq) (1991 - 2015)

Year	1 - Energy	1.A - Fuel Combustion Activities	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
1991	1177.1	1177.1	23.8	102.6	643.3	407.4	9.3
1992	1252.0	1252.0	26.1	105.4	696.3	424.1	10.9
1993	1350.1	1350.1	28.4	108.3	755.6	457.7	12.9
1994	1464.0	1464.0	30.8	111.2	806.9	500.0	15.1
1995	1473.4	1473.4	33.1	114.0	890.8	417.3	18.2
1996	1565.8	1565.8	35.4	116.9	974.6	417.8	21.2
1997	1617.1	1617.1	37.7	119.8	1058.4	376.9	24.2
1998	1758.5	1758.5	40.0	122.2	1142.3	426.8	27.3
1999	1893.5	1893.5	42.3	126.9	1226.1	467.9	30.3
2000	1933.7	1933.7	7.3	131.3	1308.8	453.0	33.3
2001	2115.5	2115.5	9.2	142.7	1442.3	483.8	37.5
2002	2163.0	2163.0	0.5	110.1	1451.4	562.8	38.3
2003	2454.2	2454.2	21.5	144.2	1670.9	575.7	42.0
2004	2521.4	2521.4	2.2	158.0	1776.5	541.1	43.6
2005	2670.7	2670.7	53.9	146.8	1897.1	529.2	43.8
2006	2823.4	2823.4	164.9	159.2	2011.2	443.1	45.0
2007	2906.9	2906.9	196.0	171.2	2113.0	381.8	45.0
2008	2751.8	2751.8	236.9	172.3	1932.5	372.5	37.6
2009	2831.6	2831.6	143.4	181.9	2062.4	405.1	38.9
2010	2923.3	2923.3	35.7	191.8	2261.1	393.2	41.5
2011	2796.3	2796.3	13.0	222.9	2122.8	392.2	45.3
2012	3003.3	3003.3	97.0	192.1	2222.3	440.7	51.4
2013	2861.0	2861.0	15.5	175.5	2265.0	352.3	52.8
2014	3234.2	3234.2	5.4	176.0	2586.6	405.1	61.1
2015	3540.0	3540.0	20.7	179.8	2931.0	408.6	108.8

*** Other sectors: include Residential and Fishing**

Transport contributed between 55 and 83% of total emissions over the period 1991 to 2015. The Other Sectors category was the second highest emitter after transport with 11.5%. Emissions from Manufacturing Industries and Construction varied between 102 and 180 but regressed from 8.7% to 5.1% of total aggregated emissions. Energy Industries emissions varied widely because local electricity generation serves only to supplement import deficits and emissions from that category which hit a maximum of 8.6% in 2008.

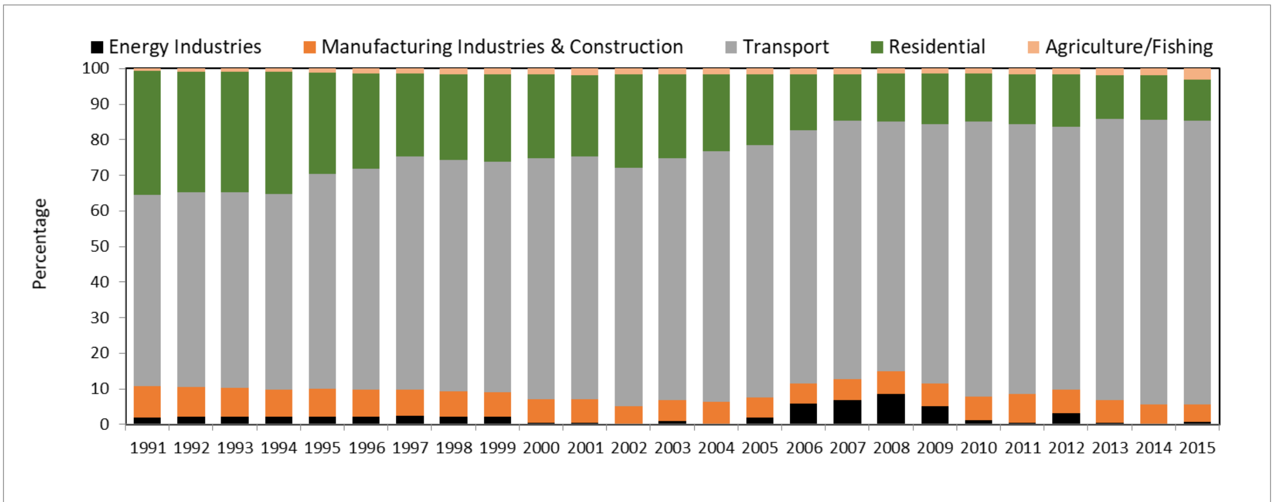


Figure 3.7 - Share of GHG emissions (Gg CO_2-eq) by Energy sub-category (1991 - 2015)

Out of the nine Energy sub-categories, Road transportation remained the major contributor of emissions (Table 3.25), expressed in terms of Gg CO_2-eq, followed by Fishing. The Residential sub-category that was emitting more than Mining in the 1990s, has remained more or less stable over the inventory period to be surpassed by Mining as from the year 2004. Emissions from the Road transportation sub-category increased from 583 Gg CO_2-eq in 1991 to reach 2742 Gg CO_2-eq in 2015.

Table 3.25 - GHG emissions (Gg CO_2-eq) by Energy sub-category (1991 - 2015)

Year	1 - Energy	1.A.1.a.i - Electricity Generation	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 Transportation	1.A.3.c - Railways	1.A.4.b - Residential	1.A.4.c.iii - Fishing (mobile combustion)	1.A.5.b.iii - Mobile (Other)
1991	1177.1	23.8	101.4	1.2	15.9	583.0	35.2	130.1	277.3	9.3
1992	1252.0	26.1	104.2	1.2	16.2	632.6	36.6	130.0	294.1	10.9
1993	1350.1	28.4	107.1	1.3	16.5	688.2	37.9	132.9	324.9	12.9
1994	1464.0	30.8	109.9	1.3	16.9	750.7	39.3	132.8	367.3	15.1
1995	1473.4	33.1	112.7	1.4	17.2	832.9	40.7	135.6	281.7	18.2
1996	1565.8	35.4	115.5	1.4	17.6	915.0	42.0	135.5	282.2	21.2
1997	1617.1	37.7	118.3	1.4	17.9	997.1	43.4	138.4	238.5	24.2
1998	1758.5	40.0	120.7	1.5	18.3	1079.2	44.7	136.5	290.3	27.3
1999	1893.5	42.3	125.3	1.6	18.6	1161.4	46.1	135.2	332.7	30.3
2000	1933.7	7.3	129.6	1.7	19.2	1243.5	46.1	128.9	324.1	33.3
2001	2115.5	9.2	141.0	1.7	19.4	1374.3	48.6	130.3	353.5	37.5
2002	2163.0	0.5	108.2	1.9	19.6	1380.6	51.1	141.5	421.3	38.3
2003	2454.2	21.5	142.4	1.9	19.8	1597.4	53.6	141.1	434.6	42.0
2004	2521.4	2.2	156.0	2.0	20.0	1700.3	56.2	141.3	399.9	43.6
2005	2670.7	53.9	144.9	2.0	20.2	1818.2	58.7	144.8	384.4	43.8
2006	2823.4	164.9	157.2	2.0	20.4	1930.8	60.0	139.0	304.0	45.0
2007	2906.9	196.0	169.2	2.0	20.5	2031.0	61.5	137.5	244.3	45.0
2008	2751.8	236.9	170.3	2.0	20.6	1854.7	57.2	147.8	224.7	37.6
2009	2831.6	143.4	179.8	2.1	20.7	1985.6	56.1	148.4	256.6	38.9
2010	2923.3	35.7	189.6	2.2	22.2	2181.0	57.9	126.0	267.2	41.5
2011	2796.3	13.0	220.8	2.1	28.7	2041.8	52.4	130.8	261.5	45.3
2012	3003.3	97.0	189.7	2.4	25.3	2140.5	56.5	126.0	314.7	51.4
2013	2861.0	15.5	173.1	2.4	25.4	2187.4	52.1	126.3	226.0	52.8
2014	3234.2	5.4	173.7	2.3	25.5	2506.7	54.3	132.1	273.0	61.1
2015	3540.0	20.7	177.4	2.4	25.7	2742.2	54.3	138.0	270.5	108.8

The evolution of emissions of direct and indirect GHGs in the Energy sector is presented in Table 3.26. CO_2 contributed the major part of the emissions of the direct gases followed by CH_4 and N_2O throughout the full time series 1991 to 2015. The contribution of CO_2 increased over the same period from nearly 96% in 1991 to just over 98% in 2015 (Figure 3.8) of aggregated emissions of the direct GHGs of the Energy sector.

Among the indirect gases (Table 3.26), 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 4.2 Gg.

Table 3.26 - Emissions (Gg) by gas for the Energy sector (1991 - 2015)

Year	Gg CO_2-eq			Gg			
	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
1991	1128.0	1.4	0.1	10.9	38.7	5.4	2.0
1992	1175.7	1.5	0.1	11.7	40.0	5.4	2.1
1993	1297.7	1.5	0.1	12.8	41.4	5.7	2.4
1994	1409.8	32.1	22.2	14.3	42.9	6.0	2.6
1995	1417.5	32.4	23.5	12.8	44.4	6.1	2.1
1996	1507.9	33.0	25.0	13.4	46.0	6.3	2.2
1997	1557.2	33.4	26.4	13.0	47.6	6.5	1.9
1998	1696.3	34.2	28.0	14.8	49.4	6.8	2.2
1999	1829.0	34.9	29.6	16.5	51.2	7.0	2.5
2000	1867.5	35.4	30.8	16.7	53.0	7.3	2.2
2001	2045.9	36.4	33.3	18.2	55.7	7.1	2.4
2002	2092.8	36.5	33.7	19.9	55.7	7.2	2.7
2003	2378.9	37.7	37.6	21.7	60.1	7.7	3.0
2004	2443.8	38.2	39.4	21.7	63.0	8.1	3.5
2005	2590.3	38.8	41.6	22.1	65.1	8.3	3.7
2006	2740.3	39.2	43.8	21.1	67.4	8.6	4.2
2007	2821.7	39.6	45.6	20.4	69.1	8.8	4.0
2008	2670.8	38.4	42.7	19.0	64.6	8.3	4.1
2009	2748.3	39.1	44.3	20.5	66.9	8.6	3.7
2010	2836.6	39.9	46.8	21.8	71.3	9.1	2.9
2011	2713.1	38.7	44.5	21.1	66.3	8.6	3.0
2012	2917.6	38.9	46.9	23.3	66.7	8.7	3.7
2013	2775.9	38.7	46.4	21.2	66.4	8.5	2.5
2014	3142.3	40.3	51.6	24.4	72.6	9.2	2.7
2015	3443.0	1.9	0.2	26.9	74.2	9.5	2.8

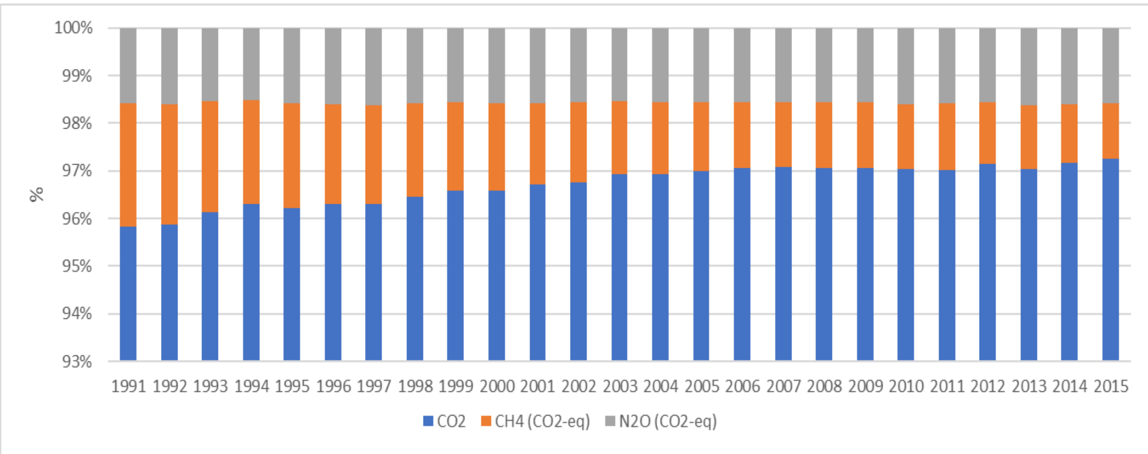


Figure 3.8 - Share emissions by gas (%) for the Energy sector (1991 - 2015)

3.3.5.3. Evolution of emissions by gas (Gg) in the Energy Sector (1991 - 2015)

Emissions of CO_2 in the Energy sector, Fuel Combustion Activities category, increased over the period 1991 to 2015, from 1,128 to 3,443 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 two years of the time series (Figure 3.9).

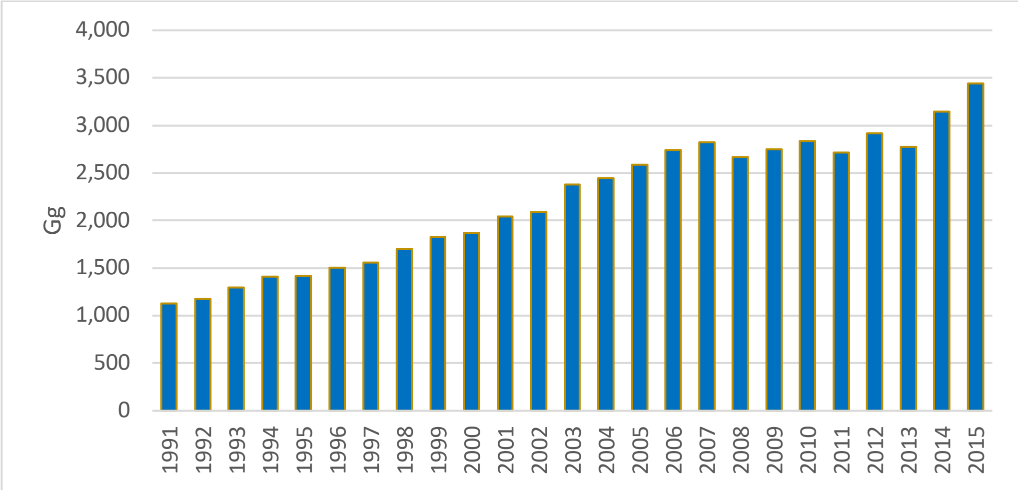


Figure 3.9 - Evolution of CO_2 emissions (Gg) in the Energy Sector (1991 - 2015)

Regarding CH_4, emissions varied between 1.5 Gg and 1.9 Gg during the period 1991 to 2015 (Figure 3.10). After increasing from 1.4 to 1.9 Gg during the period 1991 to 2007, emissions stabilised between 1.8 Gg and 1.9 Gg until 2015.

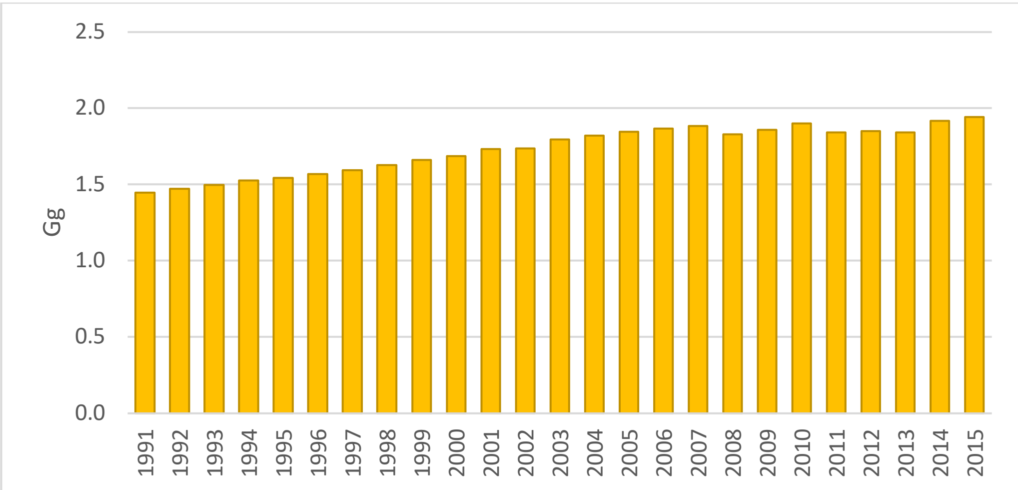


Figure 3.10 - Evolution of CH_4 emissions (Gg) in the Energy Sector (1991 - 2015)

Emissions of N_2O increased from 0.10 to 0.2 Gg (Figure 3.11) over the period 1991 to 2015.

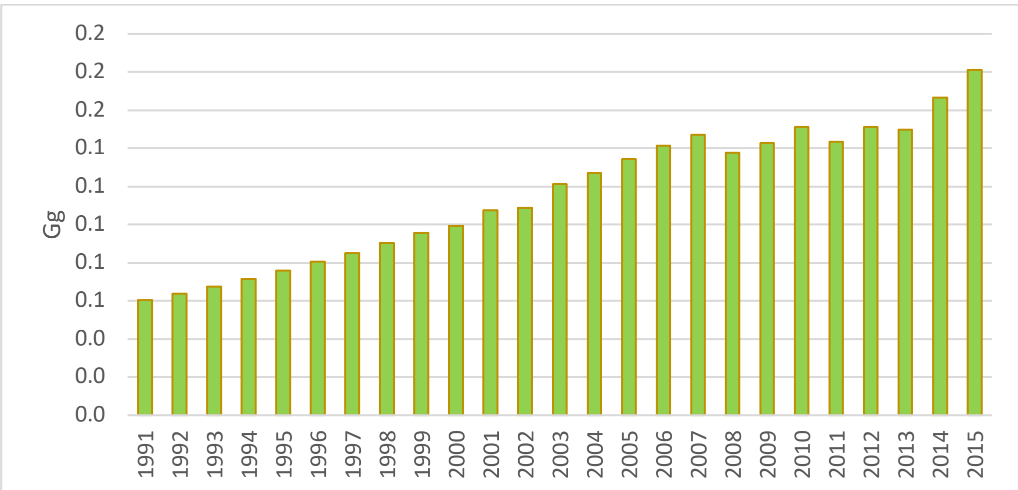


Figure 3.11 - Evolution of N_2O emissions (Gg) in the Energy Sector (1991 - 2015)

Emissions of NO_x varied from 10.9 Gg to 26.9 Gg during the period 1991 to 2015 (Figure 3.12).

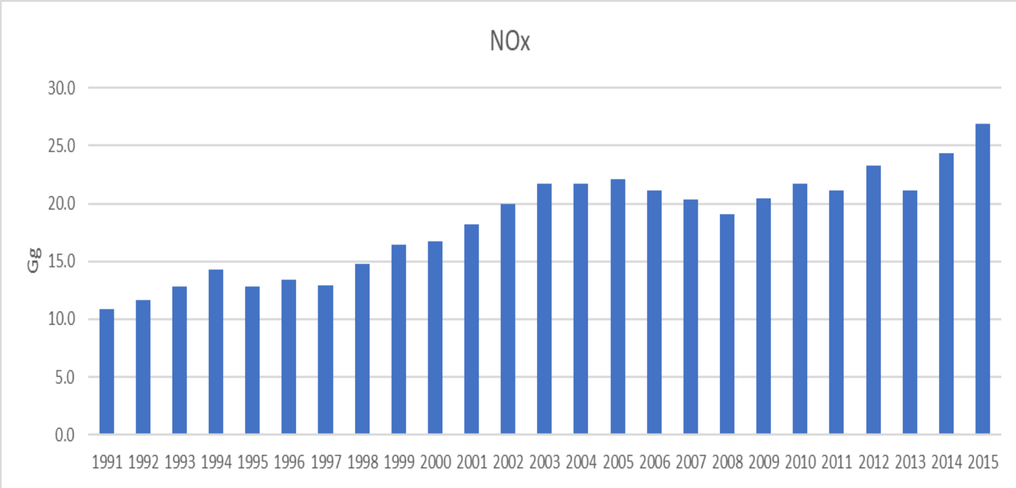


Figure 3.12 - Evolution of NO_x emissions (Gg) in the Energy Sector (1991 - 2015)

Emissions of CO varied between 38.7 Gg to 74.2 Gg from 1991 to 2015, the trend being an overall increase over the inventory period (Figure 3.13).

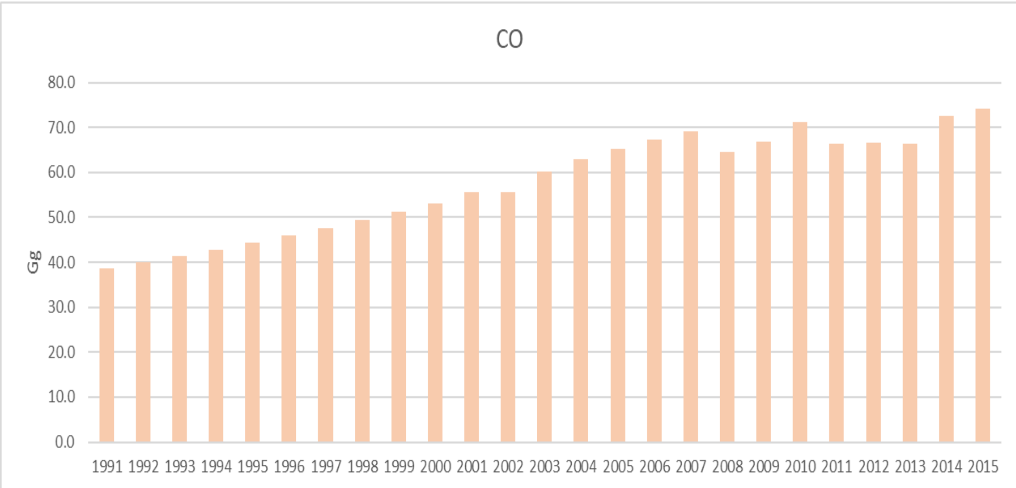


Figure 3.13 - Evolution of CO emissions (Gg) in the Energy Sector (1991 - 2015)

NMVOCs emissions varied between 5.4 and 9.5 Gg over the inventory period 1991 to 2015 (Figure 3.14).

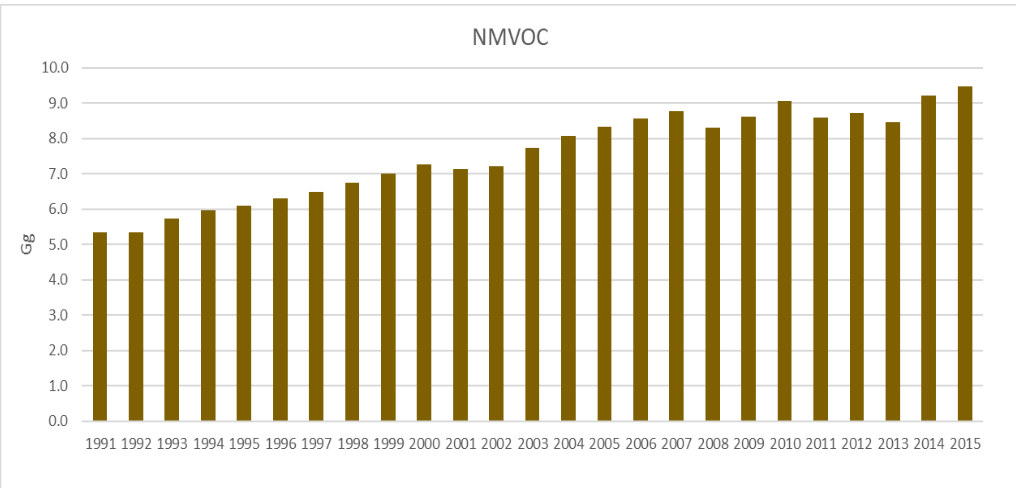


Figure 3.14 - Evolution of NMVOCs emissions (Gg) in the Energy Sector (1991 - 2015)

SO_2 emissions fluctuated between 1.9 Gg and 4.2 Gg during the inventory period 1991 to 2015 with the peak in 2006 (Figure 3.15).

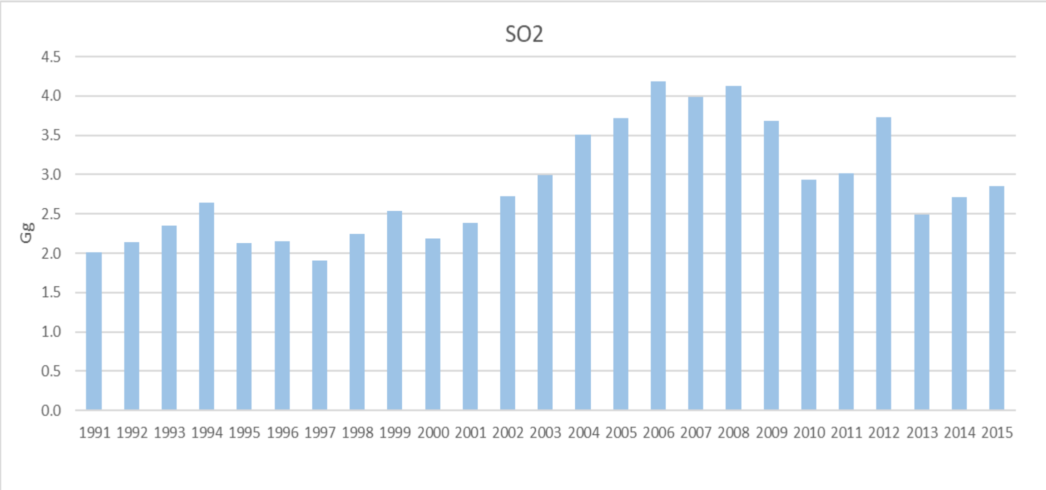


Figure 3.15 - Evolution of SO_2 emissions (Gg) in the Energy Sector (1991 - 2015)

3.3.5.4. Emissions by gas by category for the period 1991 to 2015

CO_2 emissions

Emissions (Gg) of CO_2 for the years 1991 to 2015 are summarized in Table 3.27. Total CO_2 emissions emanating from fuel combustion activities increased from 1,128 Gg in 1991 to 3,443 in 2015. For the Transport category, CO_2 emissions increased from 617 Gg in 1991 to 2,762 Gg in 2015, whilst for Energy Industries, it varied between 0.5 Gg to 235.7 Gg. Emissions from the Other sectors sub-category fluctuated between 319 Gg and 541 Gg. The Non-specified sub-category emissions increased from 9 to 107 Gg over the period under review.

Table 3.27 - CO_2 emissions (Gg) in Energy sector (1991 - 2015)

Year	Total	Energy Industries	Manufacturing Industries and Construction	Transport	Other Sectors	Non-Specified
1991	1128.0	23.7	101.9	617.3	375.9	9.1
1992	1201.4	26.0	104.8	667.5	392.3	10.7
1993	1297.7	28.3	107.6	723.6	425.6	12.6
1994	1409.8	30.6	110.5	786.4	467.4	14.9
1995	1417.5	32.9	113.4	868.4	385.0	17.9
1996	1507.9	35.2	116.2	950.5	385.1	20.8
1997	1557.2	37.5	119.1	1032.6	344.3	23.8
1998	1696.3	39.8	121.5	1114.6	393.6	26.8
1999	1829.0	42.1	126.2	1196.7	434.2	29.8
2000	1867.5	7.3	130.5	1277.7	419.2	32.8
2001	2045.9	9.2	141.8	1408.4	449.6	36.9
2002	2092.8	0.5	109.4	1417.1	528.2	37.6
2003	2378.9	21.3	143.3	1632.0	541.0	41.3
2004	2443.8	2.2	157.0	1735.2	506.6	42.8
2005	2590.3	53.6	145.8	1853.2	494.7	43.1
2006	2740.3	164.1	158.1	1964.9	409.0	44.2
2007	2821.7	195.0	170.0	2064.5	348.0	44.2
2008	2670.8	235.7	171.0	1888.3	338.8	36.9

Year	Total	Energy Industries	Manufacturing Industries and Construction	Transport	Other Sectors	Non-Specified
2009	2748.3	142.6	180.5	2015.8	371.1	38.2
2010	2836.6	35.5	190.4	2210.6	359.3	40.8
2011	2713.1	13.0	221.2	2076.0	358.4	44.5
2012	2917.6	96.5	190.6	2173.3	406.8	50.5
2013	2775.9	15.4	174.1	2215.6	319.0	51.9
2014	3142.3	5.4	174.6	2530.6	371.7	60.0
2015	3443.0	20.6	178.3	2761.9	375.3	106.9

CH_4 emissions

A total of 1.96 Gg of CH_4 was emitted from the Energy sector, Fuel Combustion Activities category in 2014 from 1.57 Gg in 1991. The main contributing sub-categories over the full period 1991 to 2015 were Other Sectors and Transport. The former emitted at 1.30 Gg and Transport 0.61 Gg (Table 3.28) in 2015. In 2015, CH_4 emissions from the Energy Industries sub-category was 0.00024 Gg and Manufacturing Industries and Construction emitted 0.034 Gg.

Table 3.28 - CH_4 emissions (Gg) in Energy sector (1991 - 2015)

Year	Total	Energy Industries	Manufacturing Industries and Construction	Transport	Other Sectors	Non-Specified
1991	1.45	0.00027	9.3E-03	0.21	1.2277	4.8E-04
1992	1.47	0.00029	9.4E-03	0.22	1.2392	5.7E-04
1993	1.50	0.00032	9.6E-03	0.23	1.2529	6.7E-04
1994	1.53	3.4E-04	9.8E-03	0.25	1.27	7.8E-04
1995	1.54	3.7E-04	9.9E-03	0.27	1.27	9.4E-04
1996	1.57	3.9E-04	1.0E-02	0.28	1.28	1.1E-03
1997	1.59	4.1E-04	1.0E-02	0.30	1.28	1.3E-03
1998	1.63	4.4E-04	1.0E-02	0.32	1.30	1.4E-03
1999	1.66	4.6E-04	1.1E-02	0.34	1.31	1.6E-03
2000	1.69	8.2E-05	1.1E-02	0.35	1.32	1.7E-03
2001	1.73	1.1E-04	1.2E-02	0.38	1.33	1.9E-03
2002	1.74	1.6E-05	9.2E-03	0.38	1.34	2.0E-03
2003	1.80	2.8E-04	1.3E-02	0.43	1.35	2.2E-03
2004	1.82	3.4E-05	1.5E-02	0.46	1.34	2.3E-03
2005	1.85	6.8E-04	1.4E-02	0.49	1.34	2.3E-03
2006	1.87	2.0E-03	1.5E-02	0.52	1.33	2.3E-03
2007	1.89	2.3E-03	1.8E-02	0.54	1.32	2.3E-03
2008	1.83	2.5E-03	1.9E-02	0.48	1.32	1.9E-03
2009	1.86	1.6E-03	2.1E-02	0.51	1.33	2.0E-03
2010	1.90	4.7E-04	2.1E-02	0.55	1.33	2.1E-03
2011	1.84	2.5E-04	2.5E-02	0.49	1.33	2.7E-03
2012	1.85	1.5E-03	2.2E-02	0.50	1.33	3.0E-03
2013	1.84	4.2E-04	2.1E-02	0.51	1.31	3.1E-03
2014	1.92	1.9E-04	2.1E-02	0.58	1.31	3.6E-03
2015	1.96	2.4E-04	3.4E-02	0.61	1.30	6.3E-03

N_2O emissions

Total emissions from the Fuel Combustion Activities category increased from 0.06 Gg in 1991 to 0.18 Gg in 2015 (Table 3.29). For all years, the highest emission was from the Transport sub-category followed by Other Sectors and Manufacturing Industries and Construction. They accounted 0.15 Gg, 0.019 Gg and 0.005 Gg respectively in 2015. In the same year, the Energy Industries sub-category emitted 0.000047 Gg of N_2O with Non-Specified sub-category contributing 0.0032 Gg.

Table 3.29 - N_2O emissions (Gg) in Energy sector (1991 - 2015)

Year	Total	Energy Industries	Manufacturing Industries and Construction	Transport	Other Sectors	Non-Specified
1991	0.06	3.7E-04	0.001	0.0399	0.018	3.7E-04
1992	0.06	4.1E-04	0.002	0.0428	0.018	4.1E-04
1993	0.07	4.4E-04	0.002	0.0460	0.019	4.4E-04
1994	0.07	4.8E-04	0.002	0.05	0.019	7.8E-04
1995	0.08	5.2E-04	0.002	0.05	0.019	9.4E-04
1996	0.08	5.5E-04	0.002	0.06	0.019	1.1E-03
1997	0.09	5.9E-04	0.002	0.06	0.019	1.3E-03
1998	0.09	6.3E-04	0.002	0.07	0.019	1.4E-03
1999	0.10	6.6E-04	0.002	0.07	0.020	1.6E-03
2000	0.10	1.1E-04	0.002	0.08	0.020	1.7E-03
2001	0.11	1.4E-04	0.002	0.08	0.020	1.9E-03
2002	0.11	3.9E-06	0.001	0.08	0.021	2.0E-03
2003	0.12	3.2E-04	0.002	0.10	0.021	2.2E-03
2004	0.13	3.1E-05	0.002	0.10	0.021	2.3E-03
2005	0.13	8.2E-04	0.002	0.11	0.020	2.3E-03
2006	0.14	2.5E-03	0.002	0.11	0.020	2.3E-03
2007	0.15	3.0E-03	0.003	0.12	0.019	2.3E-03
2008	0.14	3.7E-03	0.003	0.11	0.019	1.9E-03
2009	0.14	2.2E-03	0.003	0.12	0.019	2.0E-03
2010	0.15	5.3E-04	0.003	0.13	0.019	2.1E-03
2011	0.14	1.7E-04	0.004	0.12	0.019	2.3E-03
2012	0.15	1.4E-03	0.003	0.12	0.020	2.7E-03
2013	0.15	1.7E-04	0.003	0.12	0.019	2.7E-03
2014	0.17	4.7E-05	0.003	0.14	0.019	3.2E-03
2015	0.18	3.2E-04	0.005	0.15	0.019	5E-03

NO_x emissions

Emissions of NO_x from the combustion of fuels increased from 10.9 Gg in 1991 to 27.0 Gg in 2015. The main contributor was the Transport and Other Sectors sub-categories, followed by Manufacturing Industries and Construction, and Non-Specified sub-categories (Table 3.30). Transport emissions increased from 3.4 Gg in 1991 to 18.4 in 2015. Emissions from the Other Sectors sub-category varied between 5.6 Gg and 10.8 Gg during the period 1991 to 2015 while Energy Industries emissions fluctuated between less than 0.1 Gg to 0.52 Gg. Non-Specified sub-category emissions increased from 0.10 in 1991 to 1.11 Gg in 2015.

Table 3.30 - NO_x emissions (Gg) in Energy sector (1991 - 2015)

Year	Total	Energy Industries	Manufacturing Industries and Construction	Transport	Other Sectors	Non-Specified
1991	10.9	0.05	0.34	3.4	7.0	0.10
1992	11.7	0.06	0.36	3.7	7.4	0.11
1993	12.8	0.06	0.37	4.1	8.2	0.13
1994	14.3	0.07	0.39	4.5	9.2	0.16
1995	12.8	0.07	0.40	5.1	7.1	0.19
1996	13.4	0.08	0.42	5.6	7.1	0.22
1997	13.0	0.08	0.43	6.2	6.0	0.25
1998	14.8	0.09	0.45	6.7	7.3	0.28
1999	16.5	0.09	0.47	7.3	8.3	0.31
2000	16.7	0.02	0.48	7.8	8.1	0.34
2001	18.2	0.02	0.32	8.6	8.8	0.39
2002	19.9	0.00	0.32	8.8	10.5	0.39
2003	21.7	0.05	0.34	10.1	10.8	0.43
2004	21.7	0.00	0.58	10.8	9.9	0.45
2005	22.1	0.12	0.56	11.5	9.5	0.45
2006	21.1	0.36	0.63	12.1	7.5	0.46
2007	20.4	0.43	0.73	12.7	6.1	0.46
2008	19.0	0.52	0.77	11.8	5.6	0.39
2009	20.5	0.31	0.74	12.7	6.3	0.40
2010	21.8	0.08	0.76	13.9	6.6	0.43
2011	21.1	0.03	0.79	13.4	6.4	0.46
2012	23.3	0.21	0.75	14.1	7.7	0.52
2013	21.2	0.03	0.62	14.3	5.6	0.54
2014	24.4	0.01	0.63	16.3	6.8	0.62
2015	27.0	0.05	0.65	18.4	6.7	1.11

CO emissions

The Energy sector, Fuel Combustion Activities category CO emissions of 38.7 Gg in 1991 increased to 74.2 Gg in 2015. The emissions originated mainly from the Transport and Other Sectors sub-categories with 52.6 Gg and 20.1 Gg respectively in 2015 (Table 3.31). CO emissions from Manufacturing Industries and Construction increased from 0.10 Gg in 1991 to 1.13 Gg in 2015 while Non-Specified sub-category emissions evolved from 0.02 Gg in 1991 to 0.34 Gg in 2015. Emissions from Energy Industries were minimal.

Table 3.31 - CO emissions (Gg) in Energy sector (1991 - 2015)

Year	Total	Energy Industries	Manufacturing Industries and Construction	Transport	Other Sectors	Non-Specified
1991	38.73	2.2E-03	0.10	20.86	17.74	0.02
1992	40.01	2.5E-03	0.11	21.88	18.00	0.03
1993	41.39	2.7E-03	0.11	22.96	18.29	0.03
1994	42.4	2.9E-03	0.11	24.1	18.1	0.04
1995	43.8	3.1E-03	0.12	25.6	18.0	0.04
1996	45.6	3.3E-03	0.12	27.0	18.4	0.05
1997	47.1	3.5E-03	0.12	28.5	18.5	0.06
1998	49.1	3.7E-03	0.12	29.9	19.0	0.06
1999	50.9	3.9E-03	0.13	31.4	19.3	0.07

Year	Total	Energy Industries	Manufacturing Industries and Construction	Transport	Other Sectors	Non-Specified
2000	52.8	7.0E-04	0.13	32.9	19.7	0.08
2001	55.5	9.0E-04	0.05	35.4	19.9	0.09
2002	55.4	1.0E-04	0.06	35.1	20.2	0.09
2003	60.0	2.2E-03	0.07	39.3	20.5	0.10
2004	62.8	2.0E-04	0.97	41.3	20.5	0.10
2005	65.0	5.3E-03	0.91	43.4	20.6	0.10
2006	67.4	1.6E-02	0.93	45.8	20.6	0.11
2007	69.1	1.9E-02	0.89	47.6	20.6	0.11
2008	64.6	2.2E-02	0.84	43.1	20.6	0.09
2009	66.9	1.3E-02	1.01	45.0	20.8	0.09
2010	71.0	3.6E-03	1.10	48.9	20.9	0.10
2011	66.3	1.6E-03	1.43	43.7	21.0	0.14
2012	66.6	1.1E-02	1.11	44.2	21.1	0.16
2013	66.5	2.4E-03	1.10	45.2	20.1	0.16
2014	72.9	1.0E-03	1.11	51.2	20.3	0.19
2015	74.2	2.0E-03	1.13	52.6	20.1	0.34

NMVOC emissions

Total NMVOC emissions increased from 5.3 Gg in 1991 to 9.5 Gg in 2015. NMVOCs originated mainly from the Transport and Other Sectors sub-categories and they accounted for 5.6 Gg and 3.6 Gg of emissions of the Energy sector respectively in 2015 (Table 3.32). The other three sub-categories contributed marginally, about 0.27 Gg combined, to total NMVOC emissions.

Table 3.32 - NMVOCs emissions (Gg) in Energy sector (1991 - 2015)

Year	Total	Energy Industries	Manufacturing Industries and Construction	Transport	Other Sectors	Non-Specified
1991	5.3	2.6E-04	0.40	1.96	2.99	0.01
1992	5.5	2.9E-04	0.41	2.07	3.06	0.01
1993	5.7	3.1E-04	0.41	2.19	3.13	0.01
1994	5.9	3.0E-04	0.42	2.3	3.1	0.01
1995	6.0	4.0E-04	0.42	2.5	3.1	0.01
1996	6.3	4.0E-04	0.43	2.6	3.2	0.01
1997	6.4	4.0E-04	0.43	2.8	3.2	0.01
1998	6.7	4.0E-04	0.44	3.0	3.3	0.02
1999	7.0	5.0E-04	0.44	3.1	3.4	0.02
2000	7.2	1.0E-04	0.47	3.3	3.5	0.02
2001	7.1	1.0E-04	0.02	3.6	3.5	0.02
2002	7.2	0.0E+00	0.02	3.5	3.6	0.02
2003	7.7	3.0E-04	0.03	4.0	3.7	0.02
2004	8.0	0.0E+00	0.11	4.2	3.7	0.03
2005	8.3	6.0E-04	0.13	4.5	3.7	0.03
2006	8.6	1.9E-03	0.14	4.7	3.7	0.03
2007	8.8	2.2E-03	0.16	5.0	3.6	0.03
2008	8.3	2.5E-03	0.18	4.5	3.6	0.02
2009	8.6	1.6E-03	0.20	4.7	3.7	0.02

Year	Total	Energy Industries	Manufacturing Industries and Construction	Transport	Other Sectors	Non-Specified
2010	9.1	4.0E-04	0.20	5.1	3.7	0.02
2011	8.6	2.0E-04	0.23	4.6	3.8	0.03
2012	8.7	1.4E-03	0.20	4.6	3.8	0.03
2013	8.5	3.0E-04	0.20	4.7	3.5	0.03
2014	9.2	1.0E-04	0.20	5.4	3.6	0.04
2015	9.5	2.3E-04	0.2000	5.6	3.6	0.07

SO_2 emissions

Total SO_2 emissions in the Energy sector varied between 1.9 Gg and 4.2 Gg for the time series 1991 to 2015. 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 3.33). 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 1991 to 0.90 Gg in 2015 after a peak of 1.21 Gg in 2011.

Table 3.33 - SO_2 emissions (Gg) in Energy sector (1991 - 2015)

Year	Total	Energy Industries	Manufacturing Industries and Construction	Transport	Other Sectors	Non-Specified
1991	2.0	0.20	0.02	0.01	1.8	1.0E-04
1992	2.1	0.22	0.02	0.01	1.9	1.0E-04
1993	2.4	0.24	0.02	0.01	2.1	1.0E-04
1994	2.6	0.26	0.02	0.01	2.3	1.0E-04
1995	2.1	0.28	0.02	0.01	1.8	1.0E-04
1996	2.2	0.30	0.03	0.01	1.8	1.0E-04
1997	1.9	0.32	0.03	0.01	1.5	1.0E-04
1998	2.2	0.34	0.03	0.02	1.9	1.0E-04
1999	2.5	0.36	0.03	0.02	2.1	1.0E-04
2000	2.2	0.06	0.03	0.02	2.1	2.0E-04
2001	2.4	0.08	0.03	0.02	2.3	2.0E-04
2002	2.7	0.00	0.03	0.02	2.7	2.0E-04
2003	3.0	0.18	0.03	0.02	2.8	2.0E-04
2004	3.5	0.02	0.92	0.02	2.5	2.0E-04
2005	3.7	0.46	0.80	0.02	2.5	2.0E-04
2006	4.2	1.40	0.81	0.02	1.9	2.0E-04
2007	4.0	1.67	0.72	0.02	1.6	2.0E-04
2008	4.1	2.04	0.62	0.02	1.5	2.0E-04
2009	3.7	1.23	0.78	0.02	1.7	2.0E-04
2010	2.9	0.30	0.89	0.02	1.7	2.0E-04
2011	3.0	0.10	1.21	0.02	1.7	2.0E-04
2012	3.7	0.80	0.89	0.02	2.0	3.0E-04
2013	2.5	0.11	0.89	0.02	1.5	3.0E-04
2014	2.7	0.04	0.90	0.03	1.8	3.0E-04
2015	2.9	0.18	0.90	0.03	1.7	5.5E-04

3.3.5.5. 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 time period 1991 to 2015 due to enhanced levels of activities in both seaports and airports.

Total emissions from international bunkers are given in Table 3.34. It increased by 26% from 210.6 Gg CO_2-eq in the year 1994 to 265.6 Gg CO_2-eq in 2015. CO_2 was the major contributor with slightly more than 99% of total bunkering emissions for all years. The other direct GHGs CH_4 and N_2O contributed the remainder.

Table 3.34 - Total emissions (Gg CO_2-eq) and by gas (Gg) from international bunkers (1991 – 2015)

Year	Total CO_2-eq	CO_2	CH_4	N_2O	NO_x	CO	NMVOCs	SO_2
1991	210.62	208.58	0.014	0.006	3.73	0.590	0.20	0.601
1992	211.90	209.85	0.014	0.006	3.73	0.590	0.20	0.601
1993	213.19	211.13	0.014	0.006	3.73	0.590	0.20	0.601
1994	214.5	212.4	0.014	0.006	3.73	0.590	0.203	0.601
1995	215.8	213.7	0.013	0.006	3.71	0.583	0.201	0.592
1996	217.1	215.0	0.013	0.006	3.70	0.578	0.199	0.582
1997	218.4	216.3	0.013	0.006	3.68	0.572	0.197	0.573
1998	219.7	217.6	0.013	0.006	3.66	0.566	0.195	0.564
1999	221.0	218.9	0.013	0.006	3.65	0.561	0.193	0.554
2000	222.3	220.1	0.013	0.006	3.63	0.555	0.191	0.544
2001	225.1	223.0	0.013	0.006	2.30	0.556	0.191	0.533
2002	227.8	225.6	0.013	0.006	2.25	0.556	0.191	0.521
2003	230.5	228.3	0.013	0.006	2.21	0.557	0.191	0.509
2004	233.2	231.0	0.014	0.006	3.83	0.712	0.248	0.917
2005	235.9	233.7	0.014	0.006	3.88	0.721	0.251	0.929
2006	238.6	236.3	0.014	0.006	3.93	0.731	0.254	0.941
2007	241.3	239.0	0.014	0.006	3.98	0.740	0.257	0.953
2008	244.1	241.7	0.014	0.007	4.03	0.749	0.260	0.964
2009	246.8	244.5	0.014	0.007	4.08	0.758	0.263	0.976
2010	251.3	248.9	0.015	0.007	4.13	0.768	0.267	0.989
2011	276.3	273.7	0.015	0.007	4.31	0.793	0.276	1.019
2012	265.6	263.1	0.015	0.007	4.27	0.789	0.274	1.015
2013	265.6	263.1	0.015	0.007	4.27	0.789	0.274	1.015
2014	265.6	263.1	0.015	0.007	4.27	0.789	0.274	1.015
2015	265.6	263.1	0.015	0.007	4.27	0.789	0.274	1.015

Total emissions from international aviation increased from 66.1 Gg CO_2-eq to 109.7 Gg CO_2-eq (Table 3.35), representing an increase of 24% in 2015 over the 1991 emissions. Once more, CO_2 constituted more than 99% of the aggregated emissions of the direct gases.

Table 3.35 - Total emissions (Gg CO_2-eq) and by gas (Gg) from international aviation (1991 – 2015)

Year	Total CO_2-eq	CO_2	CH_4	N_2O	NO_x	CO	NMVOCs	SO_2
1991	66.1	65.5	0.000	0.002	0.295	0.025	0.012	0.023
1992	68.5	67.9	0.000	0.002	0.295	0.025	0.012	0.023

Year	Total CO_2-eq	CO_2	CH_4	N_2O	NO_x	CO	NMVOCs	SO_2
1993	70.9	70.3	0.000	0.002	0.295	0.025	0.012	0.023
1994	73.4	72.7	0.001	0.002	0.295	0.025	0.012	0.023
1995	75.8	75.1	0.001	0.002	0.305	0.026	0.012	0.024
1996	78.2	77.6	0.001	0.002	0.315	0.027	0.012	0.025
1997	80.7	80.0	0.001	0.002	0.325	0.028	0.013	0.025
1998	83.1	82.4	0.001	0.002	0.335	0.029	0.013	0.026
1999	85.6	84.8	0.001	0.002	0.344	0.030	0.013	0.027
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	0.035
2013	109.7	108.7	0.001	0.003	0.441	0.038	0.017	0.035
2014	109.7	108.7	0.001	0.003	0.441	0.038	0.017	0.035
2015	109.7	108.7	0.001	0.003	0.441	0.038	0.017	0.035

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 11% from 144.6 Gg CO_2-eq in 1991 to 156.0 Gg CO_2-eq in 2015 (Table 3.36).

Table 3.36 - Total emissions (Gg CO2-eq) and by gas (Gg) from international water-borne navigation (1991 – 2015)

Year	Total CO_2-eq	CO_2	CH_4	N_2O	NO_x	CO	NMVOCs	SO_2
1991	144.6	143.1	0.013	0.004	3.435	0.564	0.191	0.578
1992	143.4	142.0	0.013	0.004	3.435	0.564	0.191	0.578
1993	142.3	140.8	0.013	0.004	3.435	0.564	0.191	0.578
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	0.528
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	0.681	0.233	0.888
2005	143.4	141.9	0.013	0.004	3.505	0.689	0.236	0.900

Year	Total CO_2-eq	CO_2	CH_4	N_2O	NO_x	CO	NMVOCs	SO_2
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	0.958
2011	156.0	154.4	0.014	0.004	3.825	0.752	0.257	0.981
2012	156.0	154.4	0.014	0.004	3.825	0.752	0.257	0.981
2013	156.0	154.4	0.014	0.004	3.825	0.752	0.257	0.981
2014	156.0	154.4	0.014	0.004	3.825	0.752	0.257	0.981
2015	156.0	154.4	0.014	0.004	3.825	0.752	0.257	0.981

3.3.5.6. 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 3.37. Emissions increased by 17 % from 450.6 Gg in 1991 to 526.4 in 2015.

Table 3.37 - Emissions (Gg CO_2-eq) by gas from Biomass Combustion for Energy Production (1991 – 2015)

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
CO_2	450.6	454.1	457.6	461.1	464.7	468.2	471.8	475.4	479.1	482.7	486.4	486.8	487.1

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
CO_2	487.4	487.7	488	488.2	488.4	488.5	488.7	488.8	486.2	483.7	481.3	526.4

Table 3.38 - Sectoral Table: Energy (Inventory Year: 2015)

	Emissions (Gg)						
Categories	CO2	CH4	N2O	NOx	CO	NMVOCs	SO2
1 - Energy	3443.029	1.955	0.183	24.382	72.867	9.217	2.714
1.A - Fuel Combustion Activities	3443.029	1.955	0.183	24.382	72.867	9.217	2.714
1.A.1 - Energy Industries	20.602	0.000	0.000	0.010	0.001	0.000	0.036
1.A.1.a - Main Activity Electricity and Heat Production	20.602	0.000	0.000	0.010	0.001	0.000	0.036
1.A.1.a.i - Electricity Generation	20.602	0.000	0.000	0.010	0.001	0.000	0.036
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	NO	NO	NO	NO	NO	NO
1.A.1.c.i - Manufacture of Solid Fuels	NO	NO	NO	NO	NO	NO	NO
1.A.1.c.ii - Other Energy Industries	NO	NO	NO	NO	NO	NO	NO
1.A.2 - Manufacturing Industries and Construction	178.308	0.034	0.005	0.626	1.112	0.196	0.897
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

Categories	Emissions (Gg)						
	CO2	CH4	N2O	NOx	CO	NMVOCs	SO2
1.A.2.h - Machinery	NO	NO	NO	NO	NO	NO	NO
1.A.2.i - Mining (excluding fuels) and Quarrying	175.919	0.021	0.003	0.610	1.109	0.195	0.896
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	2.389	0.013	0.002	0.017	0.002	0.001	0.002
1.A.3 - Transport	2761.936	0.611	0.153	16.328	51.215	5.408	0.025
1.A.3.a - Civil Aviation	25.426	0.000	0.001	0.061	4.245	0.068	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	25.426	0.000	0.001	0.061	4.245	0.068	0.008
1.A.3.b - Road Transportation	2687.824	0.608	0.134	15.451	46.804	5.267	0.017
1.A.3.b.i - Cars	567.305	0.229	0.027	1.582	11.838	1.415	0.006
1.A.3.b.i.1 - Passenger cars with 3-way catalysts	182.552	0.074	0.009	0.511	3.817	0.457	0.002
1.A.3.b.i.2 - Passenger cars without 3-way catalysts	384.753	0.155	0.018	1.070	8.021	0.958	0.004
1.A.3.b.ii - Light-duty trucks	1059.942	0.323	0.052	4.768	32.521	3.229	0.009
1.A.3.b.ii.1 - Light-duty trucks with 3-way catalysts	794.957	0.242	0.039	3.576	24.390	2.422	0.007
1.A.3.b.ii.2 - Light-duty trucks without 3-way catalysts	264.986	0.081	0.013	1.192	8.130	0.807	0.002
1.A.3.b.iii - Heavy-duty trucks and buses	1058.151	0.056	0.056	9.097	2.066	0.523	0.002
1.A.3.b.iv - Motorcycles	2.426	0.001	0.000	0.005	0.379	0.100	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	375.278	1.303	0.019	6.795	20.349	3.573	1.755
1.A.4.a - Commercial/Institutional	EE	EE	EE	EE	EE	EE	EE
1.A.4.b - Residential	106.199	1.267	0.017	0.372	17.438	2.615	0.048
1.A.4.c - Agriculture/Forestry/Fishing/Fish Farms	269.079	0.036	0.002	6.423	2.911	0.958	1.707
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)	269.079	0.036	0.002	6.423	2.911	0.958	1.707
1.A.5 - Non-Specified	106.906	0.006	0.006	0.623	0.190	0.040	0.000
1.A.5.a - Stationary	EE	EE	EE	EE	EE	EE	EE
1.A.5.b - Mobile	106.906	0.006	0.006	0.623	0.190	0.040	0.000
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)	106.906	0.006	0.006	0.623	0.190	0.040	0.000
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

Categories	Emissions (Gg) CO2	CH4	N2O	NOx	CO	NMVOCs	SO2
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
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

	Emissions (Gg)						
Categories	CO2	CH4	N2O	NOx	CO	NMVOCs	SO2
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
Information Items							
CO2 from Biomass Combustion for Energy Production	526.363						

3.4 Industrial Processes and Product Use (IPPU)

3.4.1. Description of IPPU sector

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 3.39.

Table 3.39 - 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.A.2 – Lime production
2.C Metal Industry	2.C.6 – Zinc Production
2.D Non-Energy Products from Fuels and Solvent	2.D.3 – Solvent Use (7) 2.D.3.a – Wood preservation 2.D.3.b – Paint application 2.D.3.c – Asphalt and bitumen
2.F Product Uses as Substitutes for Ozone Depleting Substances	2.F.1 – Refrigeration and Air Conditioning
2.G Other Product Manufacture and Use	2.G.3 – N_2O from Product Use (Medical Applications 2.G.3.a)
2.H Other	2.H.2 - Food and Beverages Industry 2.H.2.a - Beer manufacturing 2.H.2.a – Breadmaking

A few more activity areas still have to be included given that disaggregated AD were 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

3.4.2. 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. Only emissions of CO_2, and NMVOCs were estimated, the former through computations made using the 2006 IPCC software and the latter using Excel for programming the equations recommended in the EMEP/EEA guidelines.

3.4.3. Activity Data

AD for the IPPU sector were obtained mainly from the NSA and complemented with those collected from the industrialists. Outputs from the production units and the annual report of the Chamber of Mines were used to supplement the import and export AD from the NSA for the metal industry. All AD from the different sources were compared and quality controlled to identify the most reliable sets which were then keyed 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 3.45.

3.4.3.1. 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 provided by the manufacturer. Cement production started in 2010 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 (Table 3.45).

3.4.3.2. Lime Production (2.A.2)

The amount of lime produced in Namibia steadily increased from 1991 when it stood at 2,903 tonnes to reach 22,573 tonnes in 2015. AD for the period 2000 to 2010 was obtained from the Ministry of Industrialisation, Trade and SME. The 2000 to 2005 trend was used to extrapolate data for the period 1991 to 1999 while the 2000 to 2010 trend was used to extrapolate data for the period 2011 to 2015 (Table 3.45).

3.4.3.3. Zinc Production (2.C.6)

For the purpose of this inventory, only production of metallic zinc is considered. Data obtained from the Chamber of Mines indicate that though activities were launched in 2002, it was only in 2003 that commercial production started and by 2004 had reached 119,205 tonnes. Production still grew, albeit at a slower rate, during the following years to reach 151,688 tonnes in 2010. However, thereafter production decreased significantly over the years to stand at 82,029 tonnes in 2015 (Table 3.45).

3.4.3.4. Lubricant Use (2.D.1)

Activity data gaps for Lubricant Use were filled through generation based on AD 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 1991 to 1999. Regarding 2014 and since trade data for that year was not reliable, the average usage during the period 2011 to 2013 was adopted. The time series thus obtained shows: (i) lubricant use was stable

[1] www.ohrongo-cement.com

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 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 3.45).

3.4.3.5. Paraffin Wax Use (2.D.2)

For the period 2000 to 2010, AD for Paraffin Wax Use were generated by adjusting figures obtained from the Ministry of Industrialisation, Trade and SME with data from Trade Statistics. For the periods 1991 to 1999 and that of 2011 to 2015, an estimate of 30,000 tonnes per year was used (Table 3.45).

3.4.3.6. 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 3.45).

3.4.3.7. 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 2014 was adopted to generate data for the period 1991 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 3.45).

3.4.3.8. Asphalt and bitumen (2.D.3.c)

Asphalt and bitumen import and export data available for the period 1998 to 2014 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, export data being retained for the period 1998 to 2003 and linear trending of import and export data for the period 2003 to 2014 was used to generate data for completing the time series. Asphalt and bitumen use during the period 1998 to 2003 was mainly for maintenance purposes while the steady increase from 2004 onwards was attributed to development of the road network (Table 3.45).

3.4.3.9. 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 Ozone Depleting Substances (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 ODS following the entry into force of the Montreal Protocol in 1987.

Emissions of PFCs and HFCs occur during the production of these gases, their use and when equipment containing them are retired. 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 it is retired.

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 gases by type and number of equipment imported. A study completed by GIZ 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 and AD from that study was partially used to produce a time series for this sub-category. Available information from the report that was used for estimating emissions was:

- Refrigeration and stationary air conditioning
    - New equipment sales from 2010 to 2015 for each type;
    - Existing equipment in each year from 2010 to 2015 by equipment type;
    - Charge of refrigerant gas in new equipment;
    - Refrigerant gas used in each equipment type;
    - Mobile air conditioning; and
    - Refrigerant gas used in vehicles in Namibia.

The information from 2010 to 2015 from the GIZ study was used to generate data for missing years in the timeseries for commercial refrigeration and stationary air conditioning, based on population growth of urban regions of Namibia. The growth is estimated to be 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 was used to calculate the annual number of new vehicles entering the market. The activity data generated on charge per vehicle by the number is presented in **Error! Not a valid bookmark self-reference.**. R410a gas used in stationary air conditioning consists of R32 and R125 on a 1:1 basis while R507, a 1:1 mix of R125 and R143 as well as R134a solely are used in commercial refrigeration.

Table 3.40 - Amount of refrigerant (kg) in new equipments on an annual basis

	Stationary air conditioning		Mobile air conditioning	Domestic refrigeration	Commercial refrigeration		
Year	R32	R125	R 134A	R600a	R125	R134a	R143
1993	-	-	-	9.336	-	774	-
1994	-	-	-	9,698	-	804	-
1995	6,153	6,153	6,907	10,074	4,324	835	4,324
1996	6,391	6,391	7,175	10,465	4,492	867	4,492
1997	6,639	6,639	7,453	10,871	4,666	901	4,666
1998	6,897	6,897	7,742	11,293	4,847	936	4,847
1999	7,165	7,165	8,042	11,731	5,035	972	5,035
2000	7,443	7,443	8,354	12,186	5,230	1,010	5,230
2001	7,749	7,749	8,698	12,687	5,445	1,051	5,445
2002	8,067	8,067	7,938	13,209	5,669	1,095	5,669
2003	8,399	8,398	10,382	13,751	5,902	1,140	5,902
2004	8,744	8,744	10,350	14,317	6,145	1,186	6,145

	Stationary air conditioning		Mobile air conditioning	Domestic refrigeration	Commercial refrigeration		
Year	R32	R125	R 134A	R600a	R125	R134a	R143
2005	9,103	9,103	11,081	14,905	6,397	1,235	6,397
2006	9,477	9,477	11,766	15,518	6,660	1,286	6,660
2007	9,867	9,867	12,179	16,155	6,934	1,339	6,934
2008	10,272	10,272	9,214	16,819	7,219	1,394	7,219
2009	10,694	10,694	11,553	17,511	7,516	1,451	7,516
2010	6,489	6,489	12,895	13,911	7,043	895	7,043
2011	17,440	17,440	13,942	27,942	8,957	2,242	8,957
2012	9,471	9,471	13,949	12,838	7,473	1,396	7,473
2013	17,086	17,086	14,069	12,241	8,081	1,955	8,081
2014	22,448	22,448	17,705	14,612	9,831	2,729	9,831
2015	21,010	21,010	18,029	14,986	9,318	2,385	9,318

It is assumed that all the gases came on the market in new equipment as from 1995 except R134a in domestic and commercial refrigeration as from 1993. 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 when leakage occurred will eventually be lost in leakages of following years in the lifetime of the equipment.

Emission factors

The different gases used as ODS substitutes have different GWP. EFs and details on the gases are given in Table 3.41. 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 has thus not been reported on.

Table 3.41 - Emission factors used for estimating emissions from RAC

	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	

Results

Table 3.42 summarizes emissions for the timeseries 1993 to 2015. Emissions from this sub-category is on an increasing trend, from 0.15 Gg CO_2 eq in 1993 to 113.16 Gg CO_2 eq in 2015.

Table 3.42 - Emissions (Gg CO_2 eq) from RAC (1993 – 2015)

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Emissions	0.15	0.28	5.88	11.03	15.79	20.24	24.43	28.41	32.23	35.71	40.26	47.44

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Emissions	89.35	91.00	92.64	85.84	85.68	84.60	89.69	91.15	94.65	100.68	113.16

3.4.3.10. 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 level was used to estimate the emissions from this sub-category.

Activity data

National statistics are 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 from a practicing anaesthetist)

Table 3.43 gives the activity data used.

Table 3.43 - Amount of N_2O used in medical applications on an annual basis (1991 to 2015)

Year	Population	Number of surgical operations per 100,000 persons	Total number of operations	Amount of N_2O (t) used
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

Emission factors

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

Results

Table 3.44 summarizes the emissions for the timeseries 1991 to 2015. Lowest emissions occurred in 1991 at 0.83 Gg CO_2 eq and highest emissions was recorded in 2015 at 2.45 Gg CO_2 eq. This is in direct relationship with the increasing number of operations resulting from increase in population and improvement in the healthcare system.

Table 3.44 - Emissions (Gg CO_2 eq) from N_2O in medical applications (1991 – 2015)

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Emissions	0.83	0.89	0.94	1.00	1.05	1.11	1.17	1.24	1.30	1.37	1.44	1.50	1.56

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Emission	1.63	1.69	1.76	1.83	1.90	1.97	2.05	2.12	2.20	2.28	2.36	2.45

3.4.3.11. 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 after adjustment for Namibia.

The AD so obtained show that beer production has steadily increased at an average rate of over 20,000 tonnes per year over the period of 21 years under review, to reach almost 429,000 tonnes in 2015.

3.4.3.12. 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 was computed as the average of FAO and the Agricultural Statistical Bulletin on wheat consumption. An extraction rate of 80% of the wheat was adopted to produce flour and the latter converted to bread at the rate of 610 g of flour per kg of bread.

Table 3.45 - Activity data for the IPPU sector (1991 - 2015)

Year	2.A.1-Cement production (t)	2.A.2-Lime production (t)	2.C.6-Zinc 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)	2.F.1 – Refrigeration and Air Conditioning	2.G.1 – medical Applications of N_2O	2.H.2.a-Beer manufacturing (t)	2.D.H.2.a-Bread making (wheat) (t)
1991	NO	2,903	NO	854	30,000	16	2089	485	0	2.789	8,566	32,860
1992	NO	3,652	NO	854	30,000	16	2278	485	0	2.956	6,843	41,886
1993	NO	4,402	NO	854	30,000	16	2467	485	0.15	3.130	6,986	43,913
1994	NO	5,152	NO	854	30,000	16	2,657	485	0.28	3.309	9,904	45,939
1995	NO	5,901	NO	854	30,000	16	3,169	485	5.88	3.494	9,908	55,865
1996	NO	6,651	NO	854	30,000	16	3,287	485	11.03	3.686	9,908	60,950
1997	NO	7,401	NO	854	30,000	16	3,405	485	15.79	3.884	42,141	45,646
1998	NO	8,151	NO	854	30,000	16	2,904	742	20.24	4.088	113,177	60,953
1999	NO	8,900	NO	854	30,000	16	5,169	92	24.43	4.300	156,568	75,648
2000	NO	9,161	NO	965	29,415	16	3,452	263	28.41	4.518	202,498	64,218

Year	2.A.1-Cement production (t)	2.A.2-Lime production (t)	2.C.6-Zinc 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)	2.F.1 – Refrigeration and Air Conditioning	2.G.1 – medical Applications of N_2O	2.H.2.a-Beer manufacturing (t)	2.D.H.2.a-Bread making (wheat) (t)
2001	NO	10,735	NO	448	27,319	16	3,729	1,175	32.23	4.744	258,058	65,271
2002	NO	11,200	35	294	29,577	16	5,481	1,047	35.71	4.945	185,268	83,019
2003	NO	12,400	47,436	2,022	30,332	16	2,224	2,672	40.26	5.150	264,395	80,685
2004	NO	12,600	119,205	543	34,193	16	3,415	4,297	47.44	5.360	248,612	88,614
2005	NO	13,050	132,813	6,179	30,765	16	3,524	5,921	89.35	5.575	264,516	85,699
2006	NO	13,500	129,897	6,966	29,070	16	5,108	7,546	91.00	5.795	282,645	73,770
2007	NO	14,500	150,080	11,197	29,128	16	5,542	9,171	92.64	6.020	291,301	74,914
2008	NO	15,400	145,396	14,880	34,625	16	4,885	10,796	85.84	6.250	328,516	67,798
2009	NO	17,600	150,400	15,404	35,989	16	5,723	12,421	85.68	6.486	393,881	70,136
2010	NO	19,800	151,688	13,896	27,529	16	5,883	14,045	84.60	6.723	367,496	74,892
2011	284,000	18,996	144,755	15,205	30,000	16	8,397	15,670	89.69	6.973	385,193	79,918
2012	428,000	19,890	145,342	15,231	30,000	16	5,427	17,295	91.15	7.223	410,695	85,445
2013	520,000	20,785	124,924	15,681	30,000	16	5,379	18,920	94.65	7.490	427,188	89,471
2014	583,000	21,679	102,188	15,372	30,000	16	6,809	20,545	100.68	7.757	397,039	91,879
2015	635,000	22,573	82,029	15,372	30,000	16	6,820	22,169	113.16	8.030	428,890	93,936

3.4.4. 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. 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 3.46.

Table 3.46 - Sources of EFs for the IPPU sector

Category	IPPC 2006 Guideline	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 CORINAIR – SNAP 060406	Table 3.5 – Page 15
Paint application	EMEP CORINAIR – SNAP 0601063 and 060104	Table 3.3 Page 17
Asphalt and bitumen	EMEP CORINAIR – SNAP 040611	Table 3.1 Page 8
Beer manufacturing	EMEP CORINAIR - SNAP 060407	Table 3-1 Page 7
Bread making	EMEP CORINAIR - SNAP 060405	Table 3-1 Page 7

3.4.5. Emission estimates

3.4.5.1. Aggregated emissions by gas for inventory year 2015

Direct gases and HFCs

Two direct gases CO_2 and N_2O and HFCs, were emitted from the IPPU Sector. The emissions amounted to 631.03 Gg CO_2-eq (Table 5.4). The highest emitter in 2015 was the Cement industry with 330.20 Gg CO_2-eq followed by Zinc production with 141.09 Gg CO_2-eq. The remaining sub-categories are less important emitters as depicted in Figure 3.16. The second gas in importance, the HFCs, from RAC was at 113.16 Gg CO_2-eq while N_2O, was emitted from medical uses and stood at 2.45 Gg in 2015.

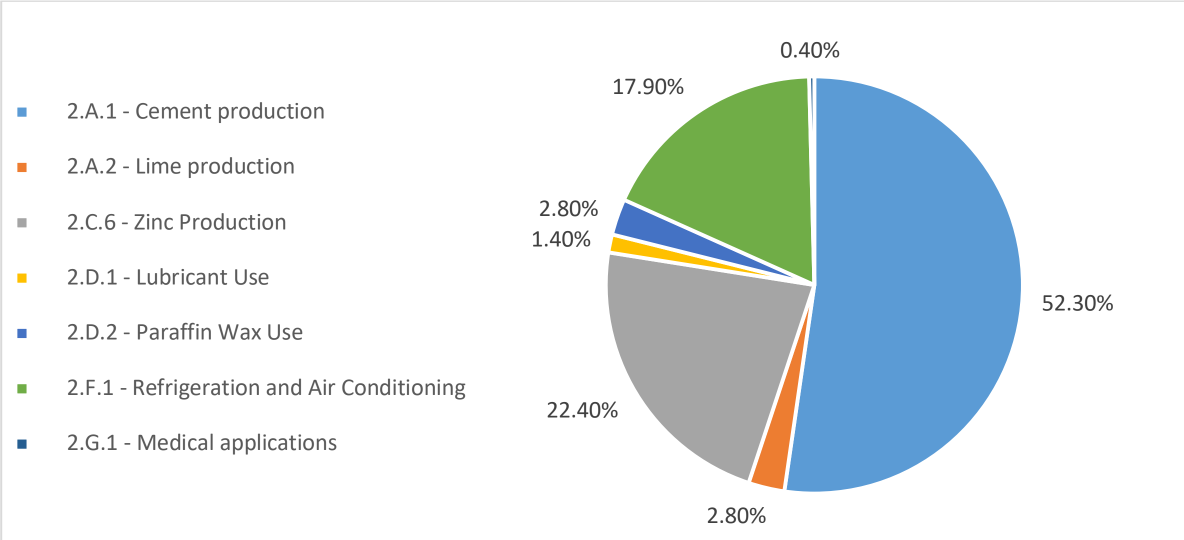


Figure 3.16 - Percentage distribution of emissions for IPPU Sector (2015)

Indirect gases

The only indirect gas that was emitted in the IPPU sector in 2015 was NMVOCs and was 2.43 Gg (Table 3.47).

Table 3.47 - Emissions from IPPU Sector categories for inventory year 2015

Categories	NMVOCs (Gg)
2 - Industrial Processes and Product Use	2.43
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	1.33
2.H.2 - Food and Beverages Industry	1.10

3.4.5.2. Emission trends of direct GHGs by category for the period 1991 to 2015

Direct gases

CO_2 emissions from IPPU Sector during the period 1991 to 2015 are given in Table 3.48. The total emissions of 631.03 Gg CO_2-eq was mainly due to Cement Production and to a lesser extent Zinc Production and RAC activities which represented 52.3%, 22.4% and 17.9% respectively. The remaining emissions originated from Paraffin Wax Use (2.8%), Lime Production (2.8%) and Lubricant Use (1.4%).

Table 3.48 - Emissions trends of Direct gases (Gg CO_2 -eq) by category of IPPU Sector for period 1991 to 2015

Year	2.A.1 - Cement production	2.A.2 - Lime production	2.C.6 - Zinc 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	IPPU Sector
1991	0	2.24	0	0.50	17.69	0	0.83	21.26
1992	0	2.81	0	0.50	17.69	0	0.89	21.89
1992	0	3.39	0	0.50	17.69	0.15	0.94	22.67

Year	2.A.1 - Cement production	2.A.2 - Lime production	2.C.6 - Zinc 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	IPPU Sector
1994	0	3.97	0	0.50	17.69	0.28	1.00	23.44
1995	0	4.54	0	0.50	17.69	5.88	1.05	29.66
1996	0	5.12	0	0.50	17.69	11.03	1.11	35.45
1997	0	5.70	0	0.50	17.69	15.79	1.17	40.85
1998	0	6.28	0	0.50	17.69	20.24	1.24	45.95
1999	0	6.85	0	0.50	17.69	24.43	1.30	50.77
2000	0	7.05	0	0.57	17.34	28.41	1.37	54.74
2001	0	8.27	0	0.26	16.11	32.23	1.44	58.31
2002	0	8.62	0.06	0.73	17.44	35.71	1.50	64.06
2003	0	9.55	81.59	1.19	17.88	40.26	1.57	152.04
2004	0	9.70	205.03	2.42	20.16	47.44	1.63	286.38
2005	0	10.05	228.44	3.64	18.14	89.35	1.70	351.32
2006	0	10.40	223.42	4.11	17.14	91.00	1.76	347.83
2007	0	11.17	258.14	6.60	17.17	92.64	1.83	387.55
2008	0	11.86	250.08	8.77	20.41	85.84	1.90	378.86
2009	0	13.55	258.69	9.08	21.22	85.68	1.97	390.19
2010	0	15.25	260.90	8.19	16.23	84.60	2.05	387.22
2011	147.68	14.63	248.98	8.96	17.69	89.69	2.12	529.75
2012	222.56	15.32	249.99	8.98	17.69	91.15	2.20	607.89
2013	270.4	16.00	214.87	9.25	17.69	94.65	2.28	625.14
2014	303.16	16.69	175.76	9.06	17.69	100.68	2.36	625.40
2015	330.20	17.38	141.09	9.06	17.69	113.16	2.45	631.03

3.4.5.3. Emission trends of Indirect GHGs by sub-category for inventory period 1991 to 2015

Indirect gases

NMVOCs emissions came from two 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 3.49). In 2015, a total amount of 2.43 Gg of NMVOCs were emitted by the IPPU sector, most of which originating from the use of solvents with 54.6% of emissions (1.33 Gg) and Food and Beverages with 45.6% of emissions at 1.10 Gg. Total emissions of NMVOCs increased from 0.52 in 1991 to 2.43 Gg in 2015.

Table 3.49 - NMVOCs emission trends for IPPU sector categories (1991 - 2015)

Year	2.D.3 - Solvent	2.H.2 - Food and Beverages Industry	Total IPPU Sector
1991	0.42	0.10	0.52
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	0.2	0.85
1998	0.68	0.39	1.07
1999	0.72	0.51	1.23

Year	2.D.3 - Solvent	2.H.2 - Food and Beverages Industry	Total IPPU Sector
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

Table 3.50 - Sectoral Table: IPPU (Inventory Year: 2015)

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	515.423	0.000	0.008	113.162	0.000	0.000	0.000	0.000	0.000	0.000	1.035	0.000
2.A - Mineral Industry	347.581	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	330.200	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.A.2 - Lime production	17.381	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.A.3 - Glass Production	0.000	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

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.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.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	141.090	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	141.090	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

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 - Non-Energy Products from Fuels and Solvent Use (6)	26.752	NO	NO	NA	NA	NA	NA	NA	NO	NO	0.000	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	17.688	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	0.000	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	NE	NE	NA	NA	NA	NA	NA	NA	NA
2.F.1 - Refrigeration and Air Conditioning	NA	NA	NA	NE	NA	NA	NA	NA	NA	NA	NA	NA
2.F.1.a - Refrigeration and Stationary Air Conditioning	NA	NA	NA	NE	NA	NA	NA	NA	NA	NA	NA	NA
2.F.1.b - Mobile Air Conditioning	NA	NA	NA	NE	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

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 - Other Product Manufacture and Use	NO	NO	NE	NO	NE	NE	NO	NE	NA	NA	NA	NA
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	NE	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	NO	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	1.035	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	1.035	0.000
2.H.3 - Other (please specify) (3)	NO	NO	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO

3.5 Agriculture, Forest and Other Land Use (AFOLU)

3.5.1. 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.

3.5.1.1. Emission estimates for the AFOLU sector

The AFOLU sector remained a sink throughout the time series. Net removals increased from 76,610 Gg CO_2-eq in the year 1991 to 104,719 in the year 2015. There was an 18% increase in emissions from the livestock category. Emissions from aggregate sources and non-CO_2 emissions from land varied from 2,957 Gg CO_2-eq to 6,538 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 86,352 Gg CO_2 in 1991 reached 111,720 Gg in 2015 (Table 3.51).

Table 3.51 - Aggregated emissions (CO_2-eq) from the AFOLU sector (1991 - 2015)

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
1991	-76,610	3,204	-86,352	6,538	0
1992	-77,526	3,133	-86,907	6,249	0
1993	-78,555	2,935	-87,415	5,925	0
1994	-79,331	2,908	-87,924	5,685	0
1995	-81,283	2,946	-89,731	5,502	0
1996	-83,514	2,846	-91,556	5,196	0
1997	-85,407	2,964	-93,398	5,026	0
1998	-87,542	3,070	-95,257	4,828	-183
1999	-89,517	3,179	-97,133	4,636	-199
2000	-91,480	3,460	-99,332	4,442	-50
2001	-91,461	3,470	-99,266	4,511	-176
2002	-96,574	3,338	-103,740	3,789	39
2003	-96,995	3,393	-104,182	3,837	-43
2004	-99,091	3,350	-106,003	3,583	-21
2005	-96,675	3,180	-103,776	3,968	-47
2006	-92,170	3,340	-100,173	4,717	-54
2007	-89,006	3,289	-97,409	5,179	-66
2008	-98,779	3,388	-106,030	3,921	-58
2009	-84,987	3,346	-94,181	5,997	-150
2010	-90,085	3,154	-98,418	5,265	-86
2011	-86,244	3,718	-95,679	5,840	-122
2012	-84,701	3,961	-94,716	6,145	-91
2013	-106,148	3,566	-112,586	2,957	-85
2014	-102,255	3,879	-109,657	3,623	-100
2015	-104,719	3,775	-111,720	3,312	-86

Table 3.52 shows the evolution in emissions of the direct and indirect GHGs. CO_2 emissions increased steadily from 8,736 Gg in 1991 to reach 9,769 Gg in 2015. However, CO_2 removals far exceeded emissions over the whole period with an increasing trend. Removals increased from 95,088 Gg in 1991

to 121,575 Gg in 2015. 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 217 Gg to 318 Gg while N_2O emissions varied 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 9.1 and 39.5 Gg, CO between 582 and 2505 Gg and NMVOCs between 9.0 and 12.6 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 as a result of better management.

Table 3.52 - Emissions (Gg) by gas for AFOLU (1991 - 2015)

Year	CO_2 - Emissions	CO_2 - Removals	CO_2 - Net removals	CH_4	N_2O	NO_x	CO	NMVOCs
1991	8,735.6	-95,087.6	-86,352.0	310.7	10.4	39.5	2,505.4	10.0
1992	8,735.6	-95,643.2	-86,907.6	299.4	10.0	37.5	2,383.3	9.8
1993	8,735.6	-96,150.6	-87,415.0	282.8	9.4	35.7	2,268.3	9.2
1994	8,735.6	-96,659.2	-87,923.6	274.0	9.2	33.8	2,152.3	9.2
1995	8,735.6	-98,466.5	-89,730.9	268.8	9.0	32.0	2,035.2	9.1
1996	8,735.6	-100,291.1	-91,555.5	256.1	8.6	30.1	1,917.2	9.0
1997	8,735.6	-102,133.0	-93,397.4	253.8	8.6	28.2	1,798.1	9.3
1998	8,735.5	-104,174.8	-95,439.2	250.7	8.5	26.3	1,678.0	9.7
1999	8,735.5	-106,067.6	-97,332.1	247.8	8.4	24.4	1,556.9	10.0
2000	8,735.8	-108,116.8	-99,381.0	251.0	8.5	22.1	1,408.3	11.0
2001	8,949.5	-108,388.4	-99,438.9	252.1	8.7	22.2	1,418.8	10.9
2002	8,987.9	-112,686.5	-103,698.7	223.6	7.8	16.8	1,072.6	10.5
2003	8,947.3	-113,171.1	-104,223.8	226.7	8.0	16.8	1,075.7	10.6
2004	8,947.0	-114,970.2	-106,023.1	216.7	7.7	14.9	956.7	10.6
2005	8,946.6	-112,769.4	-103,822.8	224.4	7.9	18.7	1,196.7	10.1
2006	8,946.6	-109,172.8	-100,226.2	254.0	8.8	24.1	1,545.7	10.7
2007	8,946.7	-106,420.8	-97,474.1	266.5	9.3	28.5	1,829.3	10.5
2008	8,946.5	-115,034.7	-106,088.2	229.4	8.0	17.6	1,129.5	10.8
2009	8,946.6	-103,276.9	-94,330.3	296.5	10.1	34.1	2,189.8	10.7
2010	8,946.5	-107,450.1	-98,503.6	266.2	9.1	29.1	1,868.1	10.3
2011	9,769.1	-105,570.1	-95,801.0	301.4	10.4	31.2	2,003.0	11.7
2012	9,769.2	-104,575.8	-94,806.6	318.4	11.0	32.5	2,091.2	12.5
2013	9,769.0	-122,439.3	-112,670.2	201.7	7.4	9.1	582.4	11.3
2014	9,769.0	-119,525.4	-109,756.5	234.0	8.3	13.3	858.0	12.6
2015	9,769.2	-121,575.0	-111,805.8	219.2	8.0	11.0	704.9	12.2

The evolution of aggregated emissions, excluding removals, of the three direct GHGs is presented in Figure 3.17. Total emissions fluctuated between 15,879 Gg CO_2-eq and 19,875 Gg CO_2-eq during the period 1991 to 2015, 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%.

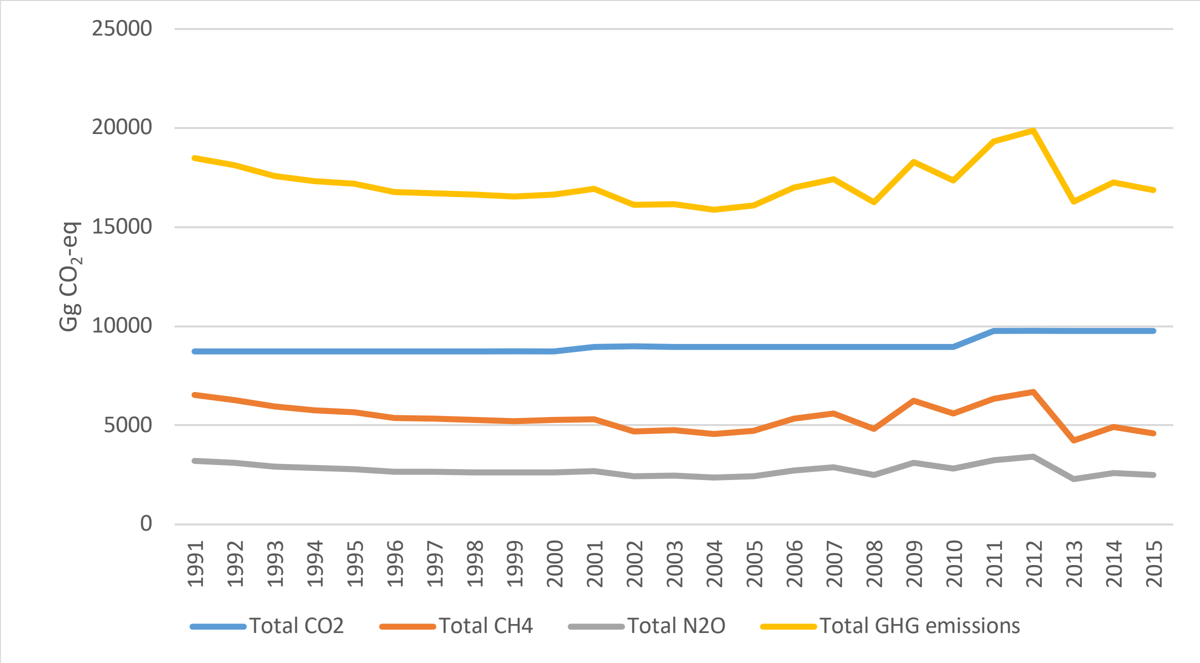


Figure 3.17 - Evolution of aggregated emissions (CO_2-eq) in the AFOLU sector (1991 - 2015)

3.5.2. Livestock

Namibia has an important livestock rearing activity, attributes 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 despite both being done on an extensive basis. An increased production in the poultry sub-category occurred during 2014 with the setting up of commercial intensive farms.

3.5.3. 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 country-specific 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.

3.5.3.1. Activity Data

Source

The FAO database was used to complete information from the NSA and annual surveys done by the Ministry of Agriculture. Priority was given to country data over the international database.

Quality control / Quality Assurance

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.

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 from 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 tourist activity.

Animal population

The population of the different livestock types used as AD for estimating emissions is provided in Table 3.53 for the years 1991 to 2015.

In order 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 done on farming practices (NNFU, 2006) in Namibia. 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 3.53 - Number of animals (1991 - 2015) by species

Year	Dairy cows	Cattle	Sheep	Goats	Horses	Mules and asses	Swine	Poultry	Camels
1991	1,500	2,211,624	3,295,447	1,991,581	51,000	68,000	16,904	502,667	-
1992	1,500	2,206,373	2,863,401	1,750,238	54,540	70,000	14,790	497,092	-
1993	1,500	2,073,540	2,651,823	1,579,856	57,391	85,000	20,065	491,518	-
1994	1,500	2,035,790	2,619,520	1,639,210	58,801	145,607	17,843	464,451	-
1995	1,500	2,031,353	2,409,699	1,616,090	53,217	145,607	19,979	487,031	-
1996	1,500	1,989,947	2,198,436	1,786,150	53,217	145,607	18,923	458,158	-
1997	1,500	2,055,416	2,429,328	1,821,009	53,217	145,607	16,884	522,618	-
1998	1,500	2,192,359	2,086,434	1,710,190	53,217	145,607	14,706	403,937	-
1999	1,500	2,278,569	2,169,651	1,689,770	53,217	145,607	18,731	450,513	-
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

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 estimates, it is necessary to also 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 3.54 below depicts the typical mature weight adopted for the different classes.

Table 3.54 - Typical animal mass

Animal type		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

3.5.3.2. Emission factors

Management practices adopted for livestock have an important bearing on the level of emissions. Both enteric fermentation and manure management EFs are dependent on 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 the cattle sub-classes. The datasets described above were used to calculate the maximum methane production capacity for the cattle sub-classes. MCF default EFs used for the different animal classes are provided in Table 3.55.

Table 3.55 - MCF values used for computing enteric fermentation emissions

Animal type		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
	Young growing female	66

Animal type		MCF (Kg CH_4/head/yr)
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 3.56 summarizes the manure management systems for the various animal categories. This is based on information available from the censuses and surveys conducted by the MAWF and NSA, while manure management system (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 previous inventories was 26°C and this was amended to 20°C as it was a mistake. In fact, Namibia falls under a temperate climate according to the IPCC Guideline except for a negligible area classified as Tropical Dry. Thus, 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 3.56 - MMS adopted for the different animal species

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 have 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.

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 was 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.

3.5.3.3. Results - Emission estimates

The emission estimates from enteric fermentation and manure management are presented in Table 3.57. Enteric fermentation contributed around 94% of total emissions of CH_4 from the livestock sector throughout the time series. Emissions increased from 3,204 Gg CO_2-eq in 1991 to 3,775 Gg CO_2-eq in 2015. The main contributor to the substantial increase as from 2013 is due to further development of the dairy industry with an increase in the number of dairy cows from 1500 to 2000 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 174 Gg CO_2-eq to 221 Gg CO_2-eq in 2015 as the manure management practice did not change much over the inventory period.

Table 3.57 - Emissions (Gg CO_2-eq) from enteric fermentation and manure management of livestock (1991 – 2015)

Year	Enteric Fermentation	Manure management
1991	3,029.8	174.3
1992	2,960.7	171.9
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	195.8
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	182.0
2006	3,138.6	201.3
2007	3,091.8	197.5
2008	3,191.4	196.6
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

The evolution of emissions of the three gases CH_4, N_2O and NMVOCs emitted by the Livestock category is given in Table 3.58. There is an increase in emissions for all three 3 gases from 1991 to 2015. The increase over the period 1991 to 2015 was of the order of 26 Gg (17.4%) for CH_4, 0.10 Gg for (28.4%) for N_2O and 2.2 Gg (22.0%) for NMVOC respectively.

Table 3.58 - Emissions (Gg) by gas for Livestock (1991-2015)

Year	CH_4	N_2O	NMVOCs
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

Year	CH_4	N_2O	NMVOCs
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	159.1	0.380	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

3.5.4. 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. Activities within the six IPCC land classes and between the classes were taken into consideration. Land use changes have 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

3.5.4.1. Description

Forestland

Forests were divided in two sub-categories and the definitions adopted for the integration of all information from FRA, RCMRD 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): There are three different land sub-classes in this sub-category:
    - Woodlands: tree height of 5 m with a canopy cover between 10% and 20%.
    - Shrubland: 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.

Cropland

Land used for annual cropping has been considered. Main crops are maize, wheat and millet and sorghum produced under both commercial and communal systems. Land under perennial crops are negligible in Namibia.

Grassland

Grassland is now redefined as a pure stand without the presence of woody biomass as in the NIR3. The grassland is estimated to be situated between the bush encroachment wetter North and East regions of the country and the desert found on the South Western part.

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.

Settlements

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

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 time series.

3.5.4.2. 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 were derived based on data from past forest inventories and other available in-country information and resources.

3.5.4.3. Activity Data

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 Forestland.

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. It has reached a point 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 represents a serious threat to the sustainability of the livestock industry. In fact, there is a programme for rehabilitating of the rangelands which is presently ongoing.

Thus, deforestation as reported in the Forest Resource Assessments (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 3.59 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 OL. 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 3.59 - Reclassification of various land classes into 3 main classes done in FRA for year 2000

Land cover description	Calibrated area in 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 the Regional Centre for Mapping Resource for Development (RCMRD) were used for generating land use changes for previous inventories. A summary of the original data is shown in Table 3.60. Explanations of the problems encountered with the original data was 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 classes disappearing in the medium term.
- Non- realistic land use changes recorded such as Settlements being converted to Forestland.
- Inclusion of vast areas with significant stocks of woody biomass under Grassland.
- The area of Other Land double that of previous studies and official country reports.

Namibia is an arid country and the use of satellite imagery to track land cover and land use change can be very misleading if not done with care. 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 to the rainy season as the canopy cover will be very different. Additionally, ground truthing of the maps were done on a restricted basis due to lack of resources.

Table 3.60 - 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

Land cover type	Year 2000 (ha)	Year 2010 (ha)
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 of meeting the requirements of the IPCC land categories. The merger also had to integrate information available with respect to bush encroachment and its related de-bushing 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)

Changes

Forestland

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 and led to the bush being so thick and more than 5 metres warranting a change in the classification.

De-bushing methods include the use of chemicals and other mechanical means to get rid of the encroacher species 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, 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 Foundation 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 encroached 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 are so slow that a tree takes 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.) depending on species and climate. 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 growing healthy trees. 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 basket, 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 the Settlement class has been included in the NIR3. Development of infrastructure to accommodate a growing urban population plus the building of infrastructures 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 observed.

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.

QC

A study by Barnes, et al, 2005 on the assessment of woody biomass stocks from forest resources arrived at 257 million 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 million m^3. This is comforting and indicates that the approach adopted, and the assumptions and derivations made from available information are 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 from 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.

Time series AD on Land Use Changes

Three time periods have been adopted for this inventory for determining land use changes between the 6 IPCC classes: 1991 to 2000, 2001 to 2010 and 2011 to 2015. Initial areas for each period and annual change used in land matrices are given in Table 3.61 to Table 3.63.

Table 3.61 - 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.

Table 3.62 - 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
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 3.63 - Total land use adjusted area and annual change used in land matrix (2011 - 2015)

Land Type category	Area (ha)			
	Year 2011	Year 2015	Annual gain	Annual loss
Forestland	7,328,707	7.083,155	10,000	71,388
OWL	57,672,871	58,429,861	289,361	100,114
Cropland	432,777	395,987	-	9,197
Grassland	4,899,273	4,542,946	90,000	208,776
Wetlands	724,608	724,608	-	-
Settlements	38,977	39,318	114	-
Other land	11,463,570	11,463,570	-	-
Total	**82,560,782**	**82,560,782**	**389,475**	**389,475**

During 2011 to 2015, 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 and in this NC4 may not be fully representative of the national situation, but it is considered better than the one adopted in the NIRs

1 and 2. 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.

Soil type

Another hurdle is the sub-division of land into 4 different soil types. The HAC and 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 2006 software when the Tier 2 level is implemented. Thus, a weighted average of the soil factors, using the areas adopted 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 3.64.

Table 3.64 - % Distribution of different soil types in Namibia

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

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 for the NIR3 and repeated for the NC4, 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) A much lower use of local wood resources which is highly supported by the results of the recent censuses.
(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 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 and 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 a common class Other Wooded Land, computation of emissions and removals in the software 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 (see worksheets thereon).
(viii) Most wood removals 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 growing.

3.5.4.4. Generated data and emission factors

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 an 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 country specific biomass stocks. Table 3.65 shows the different biomass factors derived for the Forestland, OWL and Grassland categories.

Table 3.65 - 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

Wood removals

Removal of fuelwood was indexed on its use rate 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 and converted to woody biomass and included in the fuelwood estimates.

The amount of woody biomass removed is shown in Table 3.66.

Table 3.66 - Wood removals (t) from various activities (1991 – 2015)

Year	Charcoal production	Fuelwood exported	Fuelwood collected	Poles removal	Bushblock production	Industrial consumption	Total
1991	300,000	500	191,210	164,737	*	*	656,447
1992	300,000	500	192,804	162,224	*	*	655,528
1993	300,000	500	194,406	165,727	*	*	660,633
1994	300,000	500	196,018	169,068	*	*	665,586
1995	300,000	500	197,640	172,245	*	*	670,385
1996	300,000	500	199,270	175,259	*	*	675,029
1997	300,000	500	200,911	178,111	*	*	679,522
1998	300,000	555	202,562	180,799	*	*	683,915
1999	300,000	621	204,223	183,323	*	*	688,167
2000	300,000	152	205,894	185,685	*	*	691,731
2001	300,000	122	207,577	187,946	8,000	*	703,644
2002	300,000	130	207,748	190,055	8,000	*	705,934

Year	Charcoal production	Fuelwood exported	Fuelwood collected	Poles removal	Bushblock production	Industrial consumption	Total
2003	300,000	68	207,906	193,325	8,000	*	709,299
2004	301,044	2,469	208,050	200,640	8,000	*	720,203
2005	294,031	4,486	208,180	194,950	8,000	*	709,647
2006	320,779	7,120	208,296	201,706	8,000	*	745,900
2007	374,117	7,553	208,397	197,702	8,000	*	795,768
2008	523,727	11,651	208,484	198,838	8,000	*	950,700
2009	693,161	14,251	208,557	199,816	8,000	*	1,123,785
2010	621,187	14,467	208,615	200,112	8,000	*	1,052,381
2011	465,524	14,571	208,659	204,371	8,000	*	901,125
2012	471,321	15,116	207,455	201,247	8,000	27,000	930,138
2013	549,841	14,997	206,316	201,552	8,000	30,000	1,010,706
2014	541,410	15,909	205,241	201,631	8,000	27,000	999,191
2015	645,763	19,277	204,230	201,547	8,000	27,000	1,105,817

*** Not Occurring**

Woody biomass removals were assigned as follows:

1. Charcoal from OWL as de-bushing activities are the major contributor of wood for charcoal production.
2. All fuelwood from OWL.
3. Poles removal were accounted for as 50% from Forestland and 50% from OWL during the period 1994 to 2000, 40% from Forestland and 60% from OWL during the period 2001 to 2010 and 30% and 70% as from 2011 to 2015. This mix is based on 1% population migrating from rural to urban areas and relieving the use of poles for dwellings and the shift to other building materials as well as imports of wood for construction purposes.

Area disturbed

Information from MAWF was available for years 2000 to 2014 for total area burnt. Trending technique was used to generate the areas burnt for 1994 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 3.67.

Table 3.67 - Distribution of annual area disturbed by fire (1991 - 2015)

Year	Total	Area (ha) disturbed by fire		
		Forestland	OWL	Grassland
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
2002	3,667,000	414,528	2,903,128	349,343
2003	3,663,350	410,613	2,916,389	336,348

Year	Total	Area (ha) disturbed by fire		
		Forestland	OWL	Grassland
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

Emissions and Removals estimates

Estimates of emissions and removals for the Land sector is depicted in Table 3.68. Namibia remained a sink during the whole time series. Removals resulting from biomass accumulation outpaced the emissions. Bush encroachment and its thickening is responsible for the removals and maintenance of the sink capacity. The removals in Forestland increased from -95,087.6 Gg CO_2 in 1991 to reach a peak of -122,354.6 Gg CO_2 in 2013 and regress slightly to 121,488.5 Gg CO_2 in 2015. Emissions from grassland increased from 8,671.9 Gg CO_2 to reach 9,755.9 Gg in 2015. Emissions from land converted to settlements decreased from 63.3 Gg CO_2 to 12.8 Gg CO_2 in line with converted area. Net removals varied from a minimum of -86,352.3 Gg CO_2 in 1991 to peak at -112,585.9 Gg CO_2 in 2013 and decrease to 111,719.8 Gg CO_2 in 2015.

Table 3.68 - Emissions (CO_2) for the LAND sector (1991 - 2015)

Year	3.B.1 - Forest land	3.B.3 - Grassland	3.B.5 - Settlements	Net Removals
1991	-95,087.6	8671.9	63.3	-86,352.3
1992	-95,643.2	8671.9	63.3	-86,908.0
1993	-96,150.6	8671.9	63.3	87,415.4
1994	-96,659.2	8671.9	63.3	-87,923.9
1995	-98,466.5	8671.9	63.3	-89,731.2
1996	-100,291.1	8671.9	63.3	-91,555.8
1997	-102,133.0	8671.9	63.3	-93,397.8
1998	-103,992.2	8671.9	63.3	-95,256.9
1999	-105,868.6	8671.9	63.3	-97,133.4
2000	-108,066.7	8671.9	63.3	-99,331.5
2001	-108,212.1	8888.7	57.7	-99,265.7
2002	-112,686.5	8888.7	57.7	-103,740.1
2003	-113,128.4	8888.7	57.7	-104,181.9
2004	-114,949.2	8888.7	57.7	-106,002.8
2005	-112,722.8	8888.7	57.7	-103,776.3
2006	-109,118.9	8888.7	57.7	-100,172.5
2007	-106,355.0	8888.7	57.7	-97,408.5
2008	-114,976.9	8888.7	57.7	-106,030.4
2009	-103,127.0	8888.7	57.7	-94,180.5
2010	-107,364.4	8888.7	57.7	-98,417.9

Year	3.B.1 - Forest land	3.B.3 - Grassland	3.B.5 - Settlements	Net Removals
2011	-105,447.8	9755.9	12.8	-95,679.0
2012	-104,484.9	9755.9	12.8	-94,716.2
2013	-122,354.6	9755.9	12.8	-112,585.9
2014	-119,425.6	9755.9	12.8	-109,656.9
2015	-121,488.5	9755.9	12.8	-111,719.8

3.5.5. Aggregated sources and non-CO_2 emission sources on land

3.5.5.1. 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.

3.5.5.2. Methods

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

3.5.5.3. Activity data

The activity data 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 Table 6.20. 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. The percentages N content adopted have been provided in the NIR3 (Table 6.20, Page 82). No import and export data were available for the period 1991 to 1997 and the average of 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 3.69. The very high synthetic N fertilizer used for the period 2011 to 2014 was due to a donation from a friendly country.

Table 3.69 - Amount of N (kg) used from fertilizer application (1991 - 2015)

Type of fertilizer	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	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	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
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
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

3.5.5.4. 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.

3.5.5.5. Emission estimates

The emissions for aggregate sources and non-CO_2 emissions on land are given in Table 3.70. Emissions varied between 3,312 Gg CO_2-eq and 6,538 Gg CO_2-eq for the period 1991 to 2015. This high variability in estimates is attributed to the varying areas disturbed by wildfires between years and this is very difficult to control.

Table 3.70 - Aggregated emissions (Gg CO_2-eq) for aggregate sources and non-CO_2 emissions on Land (1991 - 2015)

1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
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
3,583	3,968	4,717	5,179	3,921	5,997	5,265	5,840	6,145	2,957	3,622	3,312

The emissions for the direct and indirect GHGs are given in Table 3.71. 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 704.9 to 2504.4 Gg.

Table 3.71 - Emissions (Gg) by gas for aggregate sources and non-CO_2 emissions on Land (1991 - 2015)

Gas	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
CO_2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.5	3.0	2.1	0.9
CH_4	163.2	155.3	147.8	140.2	132.6	124.9	117.2	109.4	101.5	91.8	92.5	70.0	70.2
N_2O	10.0	9.6	9.1	8.8	8.8	8.3	8.3	8.2	8.1	8.1	8.3	7.5	7.6
NO_x	39.5	37.5	35.7	33.8	32.0	30.1	28.2	26.3	24.4	22.1	22.2	16.8	16.8
CO	2505.4	2383.3	2268.3	2152.3	2035.2	1917.2	1798.1	1678.0	1556.9	1408.3	1418.8	1072.6	1075.7

Gas	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
CO_2	0.6	0.2	0.1	0.3	0.1	0.2	0.1	0.4	0.5	0.3	0.3	0.5
CH_4	62.4	78.1	100.8	115.6	73.7	142.9	121.9	130.7	136.5	38.0	56.0	46.0
N_2O	7.3	7.5	8.4	8.9	7.7	9.7	8.7	10.0	10.6	7.0	7.9	7.6
NO_x	14.9	18.7	24.1	28.5	17.6	34.1	29.1	31.2	32.5	9.1	13.3	11.0
CO	956.7	1196.7	1545.7	1829.3	1129.5	2189.8	1868.1	2003.0	2091.2	582.4	858.0	704.9

3.5.6. Harvested Wood Products (HWP)

3.5.6.1. Description of the HWP category

Emissions from cut trees do not necessarily occur in the same year but depends 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 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 accuracy. Now that the background work has been completed, the category HWP is now covered as one of the listed improvement areas. The period 1998 to 2015 only is covered presently until activity data is sourced for the remaining years 1991 to 1997.

3.5.6.2. 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 activity data that were available.

3.5.6.3. Activity data

Available trade statistics on wood and other wood products for the period 1998 to 2015 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 2015, only to fill any existing gap and as a method of quality control of the national data available. Additionally, activity data 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. Data for fuelwood was generated since the year 1961 based on use rate and population.

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 AD for the time series 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 2015. Different groups of HS codes were analysed and regrouped according to the various activity data components required to populate the table in the software. The information which was in weight was then converted to the units required by the software. Data for fuelwood was generated since the year 1961 based on use rate and population.

The activity data was then compared to information from FAO which existed for the years 2000 to 2015. 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 were no production of wood pulp/recycled paper in Namibia. Outliers were corrected using trending technique or average based on expert judgement.

3.5.6.4. Timeseries Activity data

Activity data from HWP category are presented in Table 3.72. All components required by the software were allocated.

Table 3.72 - Activity data for HWP from trade statistics

	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

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

3.5.6.5. Emission factors

Default emission factors from the IPCC 2006 Guidelines (V4_12_Ch12-HWP Table 12.2 Page 12.17) were used for estimating emissions and removals.

3.5.6.6. 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 3.73. The HWP category constituted a sink throughout the time 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 3.73 - Emissions (Gg) from Harvested Wood Products (1998 – 2015)

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

Year	2007	2008	2009	2010	2011	2012	2013	2014	2015
Emission/Removals	-65.8	-57.8	-149.9	-85.7	-122.4	-91.0	-84.7	-99.9	-86.5

Table 3.74 - Sectoral Table: AFOLU (Inventory Year: 2015)

Categories	Net CO2 emissions / removals	Emissions (Gg)				
		CH4	N2O	NOx	CO	NMVOCs
3 - Agriculture, Forestry, and Other Land Use	-111805.813	219.242	8.008	10.954	704.878	12.464
3.A - Livestock	NA	173.227	0.442	NA	NA	12.464
3.A.1 - Enteric Fermentation	NA	169.194	NA	NA	NA	NA
3.A.1.a - Cattle	NA	147.582	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	147.399	NA	NA	NA	NA
3.A.1.b - Buffalo	NA	NO	NA	NA	NA	NA
3.A.1.c - Sheep	NA	9.867	NA	NA	NA	NA
3.A.1.d - Goats	NA	9.343	NA	NA	NA	NA
3.A.1.e - Camels	NA	0.002	NA	NA	NA	NA
3.A.1.f - Horses	NA	0.849	NA	NA	NA	NA
3.A.1.g - Mules and Asses	NA	1.489	NA	NA	NA	NA
3.A.1.h - Swine	NA	0.063	NA	NA	NA	NA
3.A.1.j - Other (please specify)	NA	NO	NA	NA	NA	NA
3.A.2 - Manure Management (1)	NA	4.034	0.442	NA	NA	12.464
3.A.2.a - Cattle	NA	2.810	0.437	NA	NA	10.399
3.A.2.a.i - Dairy cows	NA	0.002	0.002	NA	NA	0.016
3.A.2.a.ii - Other cattle	NA	2.808	0.435	NA	NA	10.383
3.A.2.b - Buffalo	NA	NO	NA	NA	NA	0.000
3.A.2.c - Sheep	NA	0.395	NA	NA	NA	0.346
3.A.2.d - Goats	NA	0.411	NA	NA	NA	1.026
3.A.2.e - Camels	NA	0.000	NA	NA	NA	0.000
3.A.2.f - Horses	NA	0.103	NA	NA	NA	0.236
3.A.2.g - Mules and Asses	NA	0.179	NA	NA	NA	0.234
3.A.2.h - Swine	NA	0.063	0.003	NA	NA	0.038
3.A.2.i - Poultry	NA	0.073	0.002	NA	NA	0.186
3.A.2.j - Other (please specify)	NA	NA	NA	NA	NA	NA
3.B - Land	-111719.812	NA	NO	NO	NO	NO
3.B.1 - Forest land	-121488.522	NA	NO	NO	NO	NO
3.B.1.a - Forest land Remaining Forest land	-120525.811	NA	NA	NO	NO	NO

Categories	Net CO2 emissions / removals	Emissions (Gg)				
		CH4	N2O	NOx	CO	NMVOCs
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
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

Categories	Net CO2 emissions / removals	Emissions (Gg)				
		CH4	N2O	NOx	CO	NMVOCs
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)	0.470	46.014	7.566	10.954	704.878	NO
3.C.1 - Emissions from biomass burning	0.000	46.014	1.359	10.954	704.878	NO
3.C.1.a - Biomass burning in forest lands	NA	45.927	1.351	10.806	702.415	NO
3.C.1.b - Biomass burning in croplands	NA	NO	NO	NO	NO	NO
3.C.1.c - Biomass burning in grasslands	NA	0.087	0.008	0.148	2.463	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	0.470	NA	NA	NA	NA	NA
3.C.4 - Direct N2O Emissions from managed soils (3)	NA	NA	5.742	NA	NA	NA
3.C.5 - Indirect N2O Emissions from managed soils	NA	NA	0.060	NA	NA	NA
3.C.6 - Indirect N2O Emissions from manure management	NA	NA	0.405	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	-86.471	NO	NO	NO	NO	NO
3.D.1 - Harvested Wood Products	-86.471	NA	NA	NA	NA	NA
3.D.2 - Other (please specify)	NO	NO	NO	NO	NO	NO

3.6 Waste

3.6.1. Description of the 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.

3.6.1.1. 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).

It is estimated that in 2015, the waste and garbage of about 41% of Namibian households was sent to waste disposal sites, about 36% being collected on a regular basis and 5% being collected irregularly. There is a sharp contrast between urban and rural areas since, while the waste of 73% of urban households was collected on a regular (65%) or irregular (8%) basis, only about 7% of the rural households has the same service (5% on a regular basis and 2% irregularly)

On average, waste collection (regular and irregular basis) remained fairly constant during the 2001 to the 2011 period, moving from about 42.2% of households having access to the service in 2001 to 42.4% in 2011. However, it should be noted, that during the same period, regular collection increased from 30.9% to 37.2% of households while irregular collection decreased from 11.5% to reach only 5.2% of households. From 2011 to 2015, the percentage of household serviced gradually decreased to reach about 41%, both regular and irregular collection decreasing slightly to 36% and 5% of households respectively.

3.6.1.2. Open Burning of Waste

It is estimated that at national level in 2015, the waste and garbage of some 32% of Namibian households were open burnt, a sharp contrast being observed between urban and rural areas, about 10% of urban households being concerned with open burning, while some 61% of their rural counterparts were concerned by the same method of solid waste management.

Trend analysis reveals that the percentage households whose waste was open burnt increased from 18.0% in 2001 to 37.8% in 2011 and thereafter decreased to about 34% in 2015. Data also show that open burning of waste is a far more frequent practice in rural areas as compared to urban ones.

3.6.1.3. Domestic Wastewater Treatment and Discharge

The estimated percentage distribution of household by type of main toilet facility for the year 2015 is given in Table 7.2. At the country level, a notable fact is that around 47 % of the population did not have any toilet facility. All regions confounded, about 41% of the households had either a private or shared flush system, of which around 60% were connected to a sewer system and 3% to a septic tank. The remaining households used ventilated pits (about 8%), latrines without ventilation system (about 4%), or had recourse to buckets (about 1%).

3.6.1.4. 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. Because of unavailable data, only the meat sector and fish processing are covered in this inventory. It should be noted that these two activities account for the major part of industrial wastewater in the country.

3.6.2. Methods

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

3.6.3. Activity Data

3.6.3.1. 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. 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 source such as the FAO; adjusting for socio-economic factors and extrapolating waste generation from Windhoek data, estimates for solid waste generation were made for the period 1995 to 2015.

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 2014 was then estimated for the other urban areas. Activity data for the period 1991 to 2015 is given in Table 3.75.

Table 3.75 - Activity data for MSW in Waste sector (1991 - 2015)

	Municipal Solid Waste (MSW) (t)			Sent to MSW (Gg)	
Year	Urban high	Urban low	Rural	Sludge	Industrial waste
1992	-	43038	71625	0.74	23.43
1993	-	45822	74419	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	34.9
2002	44.04	43.16	105.82	1.65	36.48
2003	48.07	47.48	110.97	1.72	38.13
2004	52.40	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

Year	Municipal Solid Waste (MSW) (t)			Sent to MSW (Gg)	
	Urban high	Urban low	Rural	Sludge	Industrial waste
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	102.40	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

3.6.3.2. 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 3.76.

Table 3.76 - Timeseries for use rate of different sewage systems in Namibia

Year	Urban high			Urban low			Rural		
	Centralized aerobic	Latrine	Septic Tank	Centralized aerobic	Latrine	Septic Tank	Centralized aerobic	Latrine	Septic
1991	0.738	0.041	0	0909	0.105	0022	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
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	0.0460	0.080	0.033	0.074	0.120	0.038

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 as input in the software. The evolution of the different population fraction used is given in Table 3.77.

Table 3.77 - Fraction of population living in the different areas

Year	Fraction population		
	Urban high	Urban low	Rural
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
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

The protein content in the diet of the population is also needed as an activity data for calculation of emissions from domestic wastewater. FAO data for years 1999 to 2014 is available. Trending technique was applied to generate the data for years 1994 to 1997. Table 3.78 summarizes the data for protein intake by the population.

Table 3.78 - Annual per capita protein intake in Namibia

Year	Protein intake (kg per capita / year)
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

Year	Protein intake (kg per capita / year)
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

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. Activity data for industrial wastewater is given in Table 3.79.

Table 3.79 - Activity data for industrial wastewater (1991 - 2015)

Year	Fish processing (t)	Meat and Poultry (t)
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

3.6.4. Emission factors

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

3.6.5. Emission estimates

3.6.5.1. Aggregated emissions by gas for inventory year 2015

In 2015, a total of 163.20 Gg CO_2-eq. were emitted from sector Waste. The most important contributor to emissions was CH_4 with 135.17 Gg CO_2-eq, representing 82.8 % emissions, followed by N_2O with 25.62 Gg CO_2-eq (15.7 % emissions) and CO_2 with 2.40 Gg CO_2-eq (1.5 % emissions) (Figure 3.18).

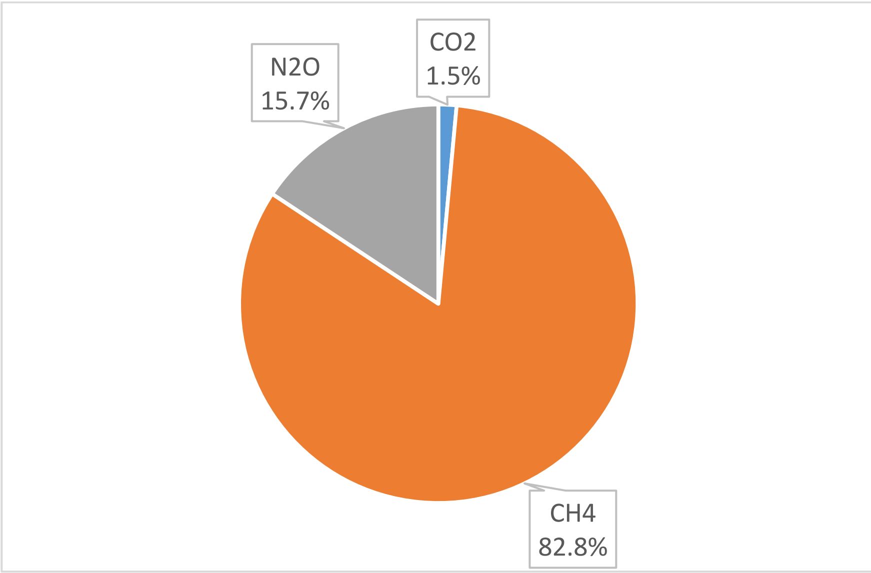


Figure 3.18 - Percentage distribution of emissions for waste Sector (2015)

3.6.5.2. Other emissions by gas for inventory year 2015

In 2015 sector Waste also emitted 0.57 Gg of NMVOCs, 0.49 Gg NO_x, 0.08 Gg N_2O and 0.02 Gg SO_2 (Figure 3.19).

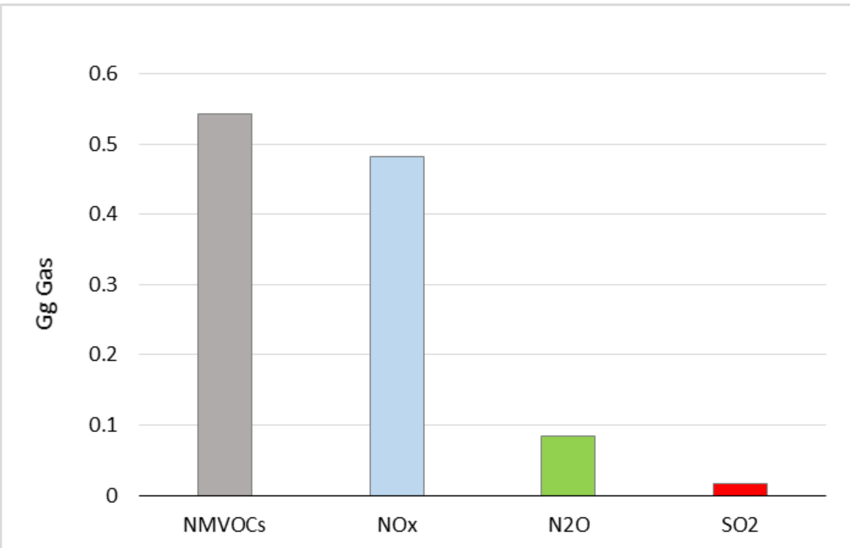


Figure 3.19 - Emissions of N_2O, NO_x, NMVOCs and SO_2 from waste Sector (2015)

3.6.5.3. Emission trend by gas for the period 1991 to 2015

Analysis of aggregated emission trend by gas (Figure 3.20) shows the following:

(i) CH_4 was the main contributor to emissions from sector waste, with 135.17 Gg CO_2-eq. in 2015, representing 82.8% of total emissions from the sector.

(ii) N_2O was the second contributor to emissions with 25.62 Gg CO_2-eq. in 2015, representing 15.7% of total emissions from the sector.

(iii) CO_2 contributed to a much lesser extent, with 2.40 Gg in 2015, representing 1.5% of total emissions from the sector.

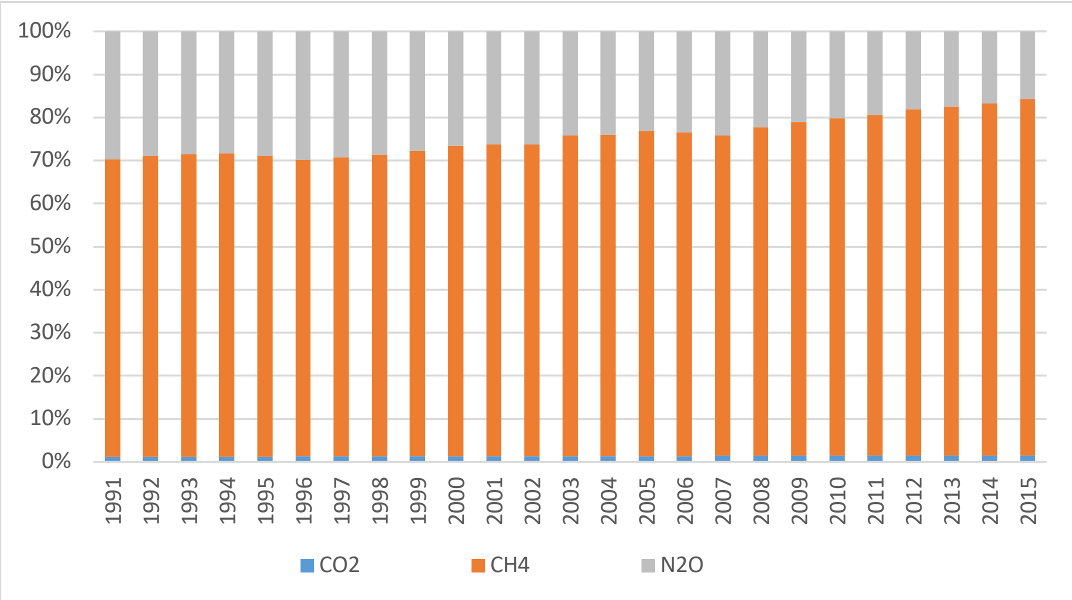


Figure 3.20 - Percentage distribution of emissions for waste Sector (1991 - 2015)

3.6.5.4. Emissions by waste category for inventory year 2015

Out of the total emissions of 163.20 Gg CO_2-eq. recorded in 2015, Solid Waste Disposal was the most important contributor with 84.18 Gg CO_2-eq. (51.6% of total), followed by Domestic Wastewater Treatment and Discharge with 34.40 Gg CO_2-eq (21.1%), Open Burning of Waste, with 27.62 Gg (16.9%) and Industrial Wastewater Treatment and Discharge, with 17.0 Gg CO_2-eq (10.4%) (Table 3.80).

During the same inventory year, sector waste also emitted 0.49 Gg NO_x, 8.64 Gg CO, 0.57 Gg NMVOC and 0.02 Gg SO_2 (Table 3.80).

Table 3.80 - Emissions from Waste sector for inventory year 2015

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	2.40	135.174	25.62	163.20	0.49	8.64	0.57	0.02
4.A - Solid Waste Disposal	-	84.18	-	84.18	-	-	0.38	-
4.A.2 - Unmanaged Waste Disposal Sites	-	76.86	-	76.86	-	-	0.38	-
4.C - Incineration and Open Burning of Waste	2.40	20.74	4.10	27.61	0.49	8.64	0.19	0.02
4.C.2 - Open Burning of Waste	2.40	20.74	4.10	27.61	0.49	8.64	0.19	0.02
4.D - Wastewater Treatment and Discharge	-	26.75	21.52	51.40	-	-	1.00E-06	-
4.D.1 - Domestic Wastewater Treatment and Discharge		12.36	21.52	34.40	-	-	8.00E-07	-
4.D.2 - Industrial Wastewater treatment and Discharge	-	14.38	-	17.00	-	-	2.00E-07	-

Table 3.81 - Sectoral Table: Waste (Inventory Year: 2015)

Categories	Gg						
	CO_2	CH4	N2O	NOx	CO	NMVOCs	SO2
4 - Waste	2.400	6.437	0.083	0.000	0.000	0.000	0.000
4.A - Solid Waste Disposal	0.000	4.009	0.000	0.000	0.000	0.000	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	NO	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	2.400	1.005	0.013	0.000	0.000	0.000	0.000
4.C.1 - Waste Incineration	NE	NE	NE	NE	NE	NE	NE
4.C.2 - Open Burning of Waste	2.400	1.005	0.013	0.000	0.000	0.000	0.000
4.D - Wastewater Treatment and Discharge	NA	1.423	0.069	NO	NO	0.000	0.000
4.D.1 - Domestic Wastewaster Treatment and Discharge	NA	0.613	0.069	NO	NO	0.000	NA
4.D.2 - Industrial Wastewater Treatment and Discharge	NA	0.809	NA	NO	NO	0.000	NA
4.E - Other (please specify)	NO	NO	NO	NO	NO	NO	NO

4. Vulnerability and Adaptation

4.1 Introduction

Within the NC reporting framework, vulnerability and adaptation assessments are aimed at outlining the conditions (climatic, environmental, and socio-economic) as they exist in the country. The assessments focus on key issues that are relevant for an improved understanding of the impacts of climate change (including risks/threats) and the vulnerability and adaptation status in the country. The information provided by the vulnerability and adaptation assessments should be relevant to the country's needs and priorities for adapting to current climate variability and future climate change.

4.1.1. Namibia's adaptation policy

Namibia has indicated its commitment to responding to climate change challenges through its National Policy on Climate Change (NPCC). The NPCC, adopted in 2011, is implemented through the NCCSAP that was finalized in 2015 for the period 2013-2020. The NPCC provides a legal framework and overarching national strategy for the development, implementation, and monitoring and evaluation of climate change mitigation and adaptation activities in Namibia.

The guiding principles of the NPCC include mainstreaming climate change into policy, legal frameworks, and development planning; ensuring that actions are country-driven and country-specific; encouraging stakeholder participation in the policy's implementation and promoting transparent planning and decision-making. The following are the goals of NPCC:

- To develop and implement appropriate strategies and actions that will lower the vulnerability of Namibians and the socio-economic sectors to the impacts of climate change;
- To effectively integrate climate change into existing policy, institutional and development frameworks in recognition of its cross-cutting nature;
- To enhance capacities and synergies at local, regional and national levels and at individual, institutional and systemic levels to ensure successful implementation of climate change response activities;
- To provide, through Government, secure and adequate funding resources for the effective adaptation and mitigation investments to climate change and associated activities (capacity building, awareness-raising, etc.); and
- To facilitate climate-proof development to reduce the magnitude and extent of impacts of climate change.

Government recognizes that many of its sectoral policies were developed before climate change emerged as a key issue for the country, and as such, these policies must be revised to better integrate climate change considerations. However, despite on-going efforts, climate change issues are not yet adequately mainstreamed into key national policies and sectoral strategies. A rapid review of national policies and sectoral strategies in key vulnerable sectors such as agriculture, water resources, tourism, and health, shows that climate change issues, although recognized, have not always been mainstreamed (Table 4.5). For instance, the National Water Policy (2008), National Health Policy Framework (2015), and National Agriculture Policy (2015), *among others*, recognize climate change as a potential risk/threat, but do not include concrete actions to mitigate climate change risks.

4.1.2. The Scope of the Vulnerability and Adaptation Assessment

Paragraph 32 of the UNFCCC states that non-Annex I Parties are encouraged to provide information on the scope of their vulnerability and adaptation assessment, including identification of most critical and vulnerable areas. Through stakeholder consultations as well as meta-analysis of available climate change literature in Namibia, it was decided that the Vulnerability and Adaptation assessment (NC4-V&A) should have two primary focus areas.

The first was to review and prioritize the most significant climate change risks, vulnerabilities, and adaptation for the following sectors: agriculture, water, tourism, health, coastal zones human settlements and ecosystems and biodiversity. The analysis of vulnerability and adaptation in the sectors mentioned above were restricted to literature, including grey literature, published after the Third National Communication (NC3). Therefore, the analysis done in this report builds on and updates the existing knowledge on vulnerability and adaptation in Namibia.

The second was an in-depth analysis of the vulnerability and adaptation of human settlements (constituencies) in Namibia to climate change impacts. The human settlement sector was selected for in-depth analysis for several reasons.

- First, human settlement was identified, by many stakeholders, as a key area that is critical to understanding and identifying Namibia's needs and priorities for adapting and mitigating the impacts of climate change.
- Second, the human settlement is one of the key sectors that is covered in the periodic Assessment Reports (AR) of the Intergovernmental Panel on Climate Change (IPCC), which has not yet been covered by past vulnerability and adaptation assessments. Despite the importance of human settlements in adaptation management, there is very little information and evidence, of how this area is responding. Thus, the need to address this gap by undertaking a vulnerability and adaptation assessment of human settlements across Namibia.
- Third, the high concentrations of people, economic activity and infrastructure arguably makes the human settlement sector as one of the most significant sectors on which the impacts of climate change play out. The vulnerability of settlements in Namibia is impacted by various and complex socio-economic processes related to the cultural, political and institutional contexts and demographic pressure, as well as specific high-risk zones susceptible to droughts, floods, and water scarcity. Resilient settlements can sustain themselves by coping with, or adapting to climate change threats, whereas vulnerable settlements are to varying degrees unable to cope with the adverse effects of climate change and experience some form of harm when a hazard occurs. Therefore, identifying settlements that are resilient or vulnerable is critical to climate change adaptation management in Namibia.
- Fourth, since climate change impacts play out at the local level, understanding the underlying key processes that drive climate change risk and vulnerability on human settlements is also crucial for effective climate change adaptation management. Understanding vulnerability at the settlement level will enable the design and implementation of adaptation measures/interventions that contextualize local conditions. These types of adaptation actions are usually very effective in mitigating current and future impacts of climate change.

4.1.3. Purpose and Objectives

Under the reporting framework of the UNFCCC, vulnerability and adaptation assessments are designed and undertaken to provide information on: (i) observed and expected impacts of climate change; (ii) vulnerabilities of specific human systems (livelihood), areas or sectors to current climate variability and future climate change; (iii) difficulties or barriers to adaptation in critical areas or sectors; and (iv) opportunities and priorities for adaptation. Therefore, the NC4-V&A contextualizes these information requirements for key sectors in Namibia. More specifically, the following were the objectives of the NC4-V&A:

(i) To review and identify the most significant information on climate trends and projections for Namibia to prioritize adaptation actions;

(ii) To review and identify the most significant climate change risks, vulnerabilities, and adaptation for the sectors agriculture, water resources, tourism, health, coastal zones, human settlements and ecosystems, and biodiversity;

(iii) To conduct an in-depth analysis of vulnerability to climate change impacts of human settlements (constituencies) of the country; and

(iv) To provide updated information on responses to climate change.

4.1.4. Unit of Analysis

The units of analysis adopted for the NC4-V&A were at sector and constituency levels. Sectors and constituencies can be regarded, to a limited extent, as homogenous systems that allow for the aggregation of vulnerability. Furthermore, sectors and constituencies are also the lowest scale of development planning in Namibia. Most climate change adaptation programs in Namibia are usually implemented at sector and constituency levels.

4.1.5. General Methodological Approach to the Assessments

In accordance with paragraph 30 of the UNFCCC, all the frameworks that were used to assess vulnerability and adaptation in the NC4-V&A are transparent and well documented.

To provide information on climate trends and projections, the NC4-V&A conducted a rapid analysis of climate data (i.e., temperature and precipitation), relevant for Namibia, extracted from the Fifth Assessment Report (AR5) of the IPCC (IPCC, 2014). Information on current and expected future impacts of climate change was primarily based on the study by the Adaptation at Scale in Semi-Arid Regions (ASSAR) project titled: 'w*hat global warming of 1.5°C and higher means for Namibia'* (ASSAR, 2019). Other literature sources, since the NC3, complemented this information.

A sectoral approach was undertaken to assess the vulnerability of key sectors in Namibia to climate change. This approach, which is consistent with the past vulnerability assessments, prioritized the most significant climate change risks and vulnerabilities in the agriculture, water resources, health, coastal zones, human settlements, ecosystems and biodiversity, food security and tourism. The exposure, sensitivity and adaptative capacity of sectors mentioned above are analysed to understand their vulnerabilities and risks they face.

An index-based approach, based on the IPCC definition of vulnerability, was used as the primary criterion for measuring the vulnerability (i.e., exposure, sensitivity and adaptive capacity) of constituencies (i.e., human settlements) across Namibia to climate change impacts/risks. The index-based approach is used because of its simplicity and ability to bridge communication between the academic world and policymakers. Despite the limitations of index-based approaches, such as those highlighted by Barnett, at al. (2008); Eriksen and Kelly (2006); Klein (2009); and Hinkel (2011), they are useful because they synthesize complex information such as the vulnerability of human settlements into a single number that can then be easily used by policymakers (Hinkel, 2011).

Information on adaptation responses, investments, barriers, and opportunities was generated through a rapid meta-analysis of recent literature post NC3 on on-going adaptation efforts across constituencies in Namibia. Additional key documents that were used in the adaptation analysis included: previous NCs; National Development Plans; National Policy on Climate Change (NPCC); and National Climate Change Strategic Action Plan (NCCSAP) 2013-2020; *among others*. Information on adaptation responses and investments were primarily extracted from national and international institutions that are active within Namibia's climate change adaptation framework.

4.1.6. Definition of Key Terms

In line with Paragraph 30 of the UNFCCC, this section defines vulnerability to climate change as a function of a system's exposure, sensitivity, and adaptive capacity. These components of vulnerability are defined below.

- *Exposure* is the presence of people, livelihoods, species or ecosystems, environmental services and resources, infrastructure, or economic, social, or cultural assets in places that could be affected by climate change or the nature of climate change itself, e.g., change in sea level, temperature, extreme events;
- *Sensitivity* is "the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise)" (McCarthy et al., 2001).
- *Adaptive capacity* is "the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (McCarthy et al., 2001). Adaptive capacity is determined by economic resources; technology; information and skills; infrastructure; institutions; and equity (Smit et al., 2001). All these elements are necessary to enhance adaptive capacity. Limitation in one can affect the overall adaptive capacity (Yohe and Tol, 2002).

Therefore, vulnerability is defined by the IPCC as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity" (McCarthy et al., 2001). The greater the exposure or sensitivity, the greater the vulnerability; the greater the adaptive capacity, the lower the vulnerability. An assessment of vulnerability must consider all these components to be comprehensive.

An *impact* of climate change is typically the effect of climate change. For biophysical systems, it can be the change in productivity, quality, or population numbers or range. For societal systems, impact can be measured as change in value (e.g., gain or loss of income) or in morbidity, mortality, or other measure of well-being (Parry and Carter, 1998).

The IPCC defines *adaptation* as, "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (Smit et al., 2001). Note that the definition includes "actual" (endured) as well as "expected" (future or anticipated) changes in climate. Thus, adaptation can be happening in response to perceived change in climate or anticipation of future change in climate. Autonomous adaptation is adaptation implemented by affected entities such as individuals, societies, or nature in response to observed or perceived changes in climate. Anticipatory or proactive adaptation is made to reduce impacts and risks from future changes in climate.

4.2 Current climate and projected changes

The following section provides information on the baseline climate (1981-2018); the trend (1901-2016); and the projections for mid-century (2040-2069) and end-century (2070-2099). The data that was used in the analysis of Namibia's climate were extracted from the AR5 of the IPCC accessed from the World Bank Climate Change Knowledge Portal[2] and also from the Namibia Climate Analysis Report. The data, used for climate projection analyses, were generated from an ensemble of eight General Circulation Models (GCMs) that were based on the worst-case emission scenario (i.e., a2). Under the a2 emission scenario it is assumed that: (i) the world evolves in a very heterogeneous way; (ii) the world population reaches 15

[2] https://climateknowledgeportal.worldbank.org/download-data

billion people in 2100 and rising; and (iii) economic growth and the spreading of new efficient technologies are very different depending on the region of the world. The a2 emission scenario is the worst-case because it results in higher global temperature projections for mid- and end-century relative to the other emission scenarios (i.e., a1, b1, etc.).

When undertaking the baseline and trend analyses, and projections, it is always important to address the uncertainties associated with results generated. These uncertainties are key to the interpretation and use of the analysis results for vulnerability assessment as well as management of climate change adaptation. However, uncertainty does not imply low confidence in the trend and projections, but rather lack of sufficient data points and observations to statistically validate the results. Indeed, all climate projections, including seasonal forecasts, are couched in terms of the probability of certain climate conditions appearing in the future. This is the framework within which humans often operate, allowing an assessment of future risks, e.g. consideration of financial and investment opportunities.

Uncertainties in climate trend analysis and climate projections arise from natural variability of climate parameters; future emissions scenarios; inherent uncertainty associated with climate change science; and the downscaling of climate data from General Circulation Models (IPCC, 2014). Therefore, to minimize the uncertainty associated with trend analysis and projections, one needs to consider all sources of information.

4.2.1. Baseline Climate

The data used to generate the baseline climate, temperature and precipitation, for Namibia were the medium-term records (1981-2018) of temperature and precipitation, which were statistically downscaled from an ensemble of 35 GCMs. The data was sourced from the Climatic Research Unit (CRU) of the University of East Anglia.

4.2.1.1. Baseline Precipitation (1981-2018)

Mean annual rainfall ranged between 25 mm to just above 600 mm (Figure 4.1), largely because of its proximity to the northward-flowing Benguela current, which brings cold water to its western shores. This cold water is advected from the south and is partly driven by a high-pressure system over the South Atlantic (known as the South Atlantic anticyclone). The combination of cold water and high pressures leads to subsidence of cold, dry air over much of Namibia, which generally suppresses rainfall. This situation is dominant during most of the year, except in summer when heating of the continent is greatest, and the southerly position of the Inter-Tropical Convergence Zone (ITCZ) draws moisture and rainfall from the tropics over northern and eastern Namibia. This situation results in a rainfall season spanning over summer months of November to April during which most rain occurs in the form of localized showers and thunderstorms. The intensity of such occurrences is dependent on the flow of tropical moisture, which is in turn dependent on the positioning of tropical easterly waves and Tropical Temperate Troughs (TTT), which transport moisture to the south (Dirkx *et al.,* 2008).

During winter mid-latitude storms pass to the southwest over South Africa. While these systems generally pass to the south of Namibia, when in a northerly position they can bring rain to the southern parts of the country accounting for more than half of the annual total. This rainfall may be enhanced in regions of steep topography. In the extreme Southwest, winter rain and even snow can be expected between June and August. The inter-annual coefficient of variation of rainfall is very high, ranging from 25% in the Northeast to >80% in the southwest.

Fog constitutes another source of moisture in the cooler coastal regions where it may reduce visibility by as much as 146 days per year. This moisture source is especially important to biota and desert plant species, and it is not currently known how climate change will affect its intensity and distribution (Dirkx *et al.,* 2008).

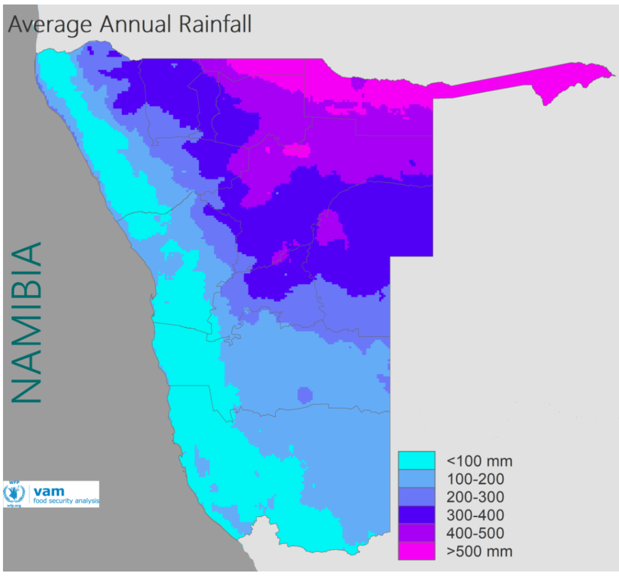


Figure 4.1 - Annual rainfall in Namibia, at 5 km resolution (1981 - 2018)
Source: Namibia Climate Analysis Report (WFP, 2019)

Occasionally during the autumn and more frequently spring seasons, low-pressure systems known as coastal lows, may develop over the west coast. These shallow systems propagate to the south and cause offshore airflow from the interior at their leading-edge (promoting warm, dry conditions) and onshore flow at the trailing edge (promoting colder conditions). Cut-off low-pressure systems are also found during these seasons and spin-off from mid-latitude frontal storms to the south. These systems often move slowly and can result in heavy rains and flooding, especially if fed with moist tropical air from the north (Dirkx *et al.,* 2008).

4.2.1.2. Baseline Temperature (1981-2018)

Although Namibia is generally considered to be hot, temperature across the country is highly variable from day to day, seasonally and over much longer periods. The average maximum temperature during the hottest months (September to February) is usually above 30°C, except for the much cooler coastal areas. July is the coolest month over much of the country, with average minimums of less than 10°C. For the coastal areas, average minimum temperatures are usually above 10°C due to the moderation effects of coastal winds (Atlas of Namibia, 2009). Figure 4.2 shows the average annual maximum temperature across Namibia.

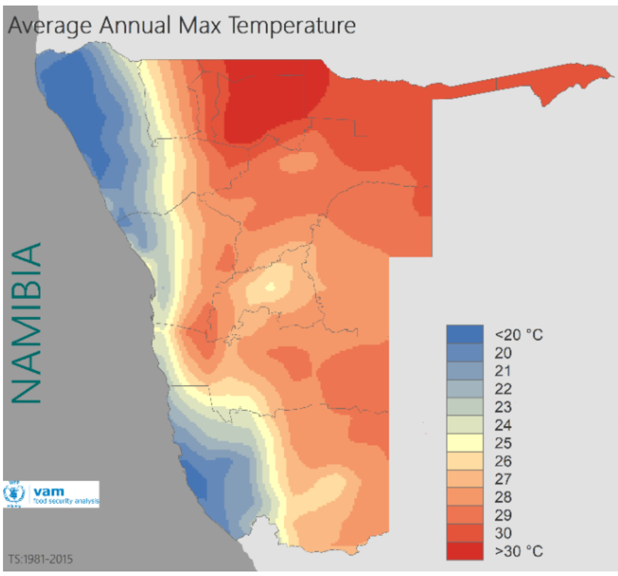


Figure 4.2 - Average annual maximum air temperature (1981 - 2018)
Source: Namibia Climate Analysis Report (WFP, 2019)

4.2.2. Climate Trends (1901-2016)

AR5 of the IPCC (IPCC, 2014) states with high confidence that there have been significant and detectable changes in temperature and precipitation over the Southern Africa region during the last 50 years and that the drivers of these changes are anthropogenic activities. Midgley et al. (2005) and New et al. (2006) are among the few studies that have analysed the historical trends in climate over Namibia. Despite the high variability associated with climate in arid environments, there is clear evidence of a detectable change in Namibia's climate, consistent with observed changes at the global and regional levels. While past trends are no guarantee of future change, especially in the context of the high variability highlighted earlier, they are the foundation from which to assess current vulnerability to climate change. Historical climate trends and changes also provide a context within which to understand the key processes that drive vulnerability at constituency level. A brief overview of historical temperature and precipitation trends observed over Namibia during the period 1901 to 2018 follows.

4.2.2.1. Air temperature (1901-2016)

The historical trend in temperature is presented in Figure 4.3 and Figure 4.4. Figure 4.3 spatially presents the rate of change in the average annual temperature while Figure 4.4 shows a plot of the average annual temperature during the period 1901-2016. Figure 4.4 shows that on average the average annual temperature in Namibia has been increasing at a rate of 0.0123°C annually over the period 1901-2016. The results presented in Figure 4.3 and Figure 4.4 are consistent with those of Midgley et al. (2005), New et al. (2006) and Dirkx et al. (2008). The statistical confidence of the results in Figure 4.3 and Figure 4.4 is presented in Figure 4.5. It is clear, from Figure 4.5, that the statistical confidence in temperature change is significant. Therefore, it can be concluded with *high confidence* that Namibia has progressively become warmer/hotter over the period 1901-2016. Furthermore, the trend shown in Figure 4.4 (i.e., 0.0123°C per year) explains about 55.69 percent (the R^2 value of the trend) of the variation in the average annual temperature observed over the period 1901-2016.

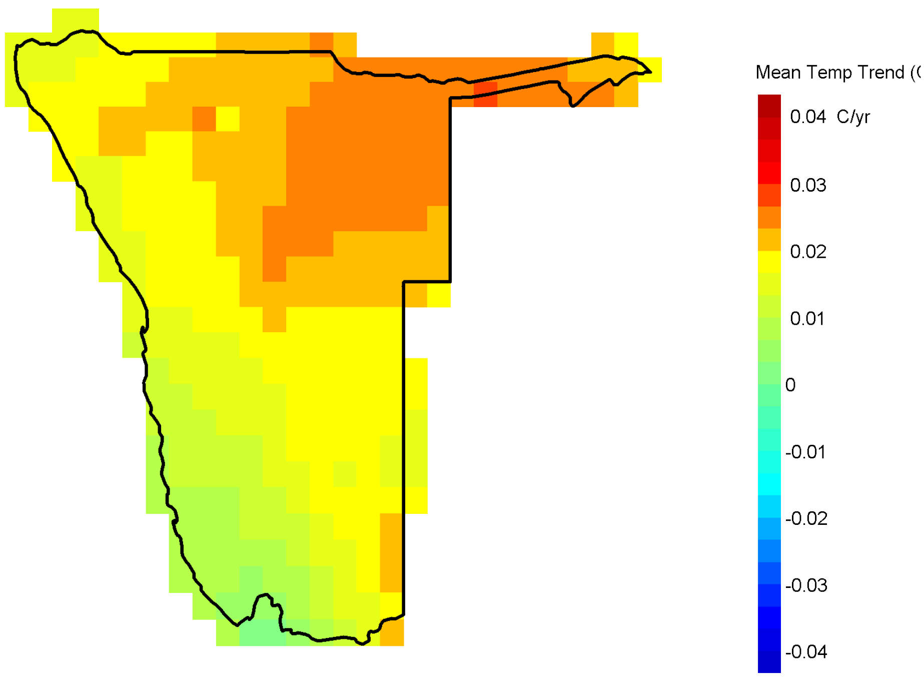


Figure 4.3 - Historical rate of change for temperature, at 0.5 degree resolution (1901 - 2016)
Source: generated by the author using CRU dataset (2019)

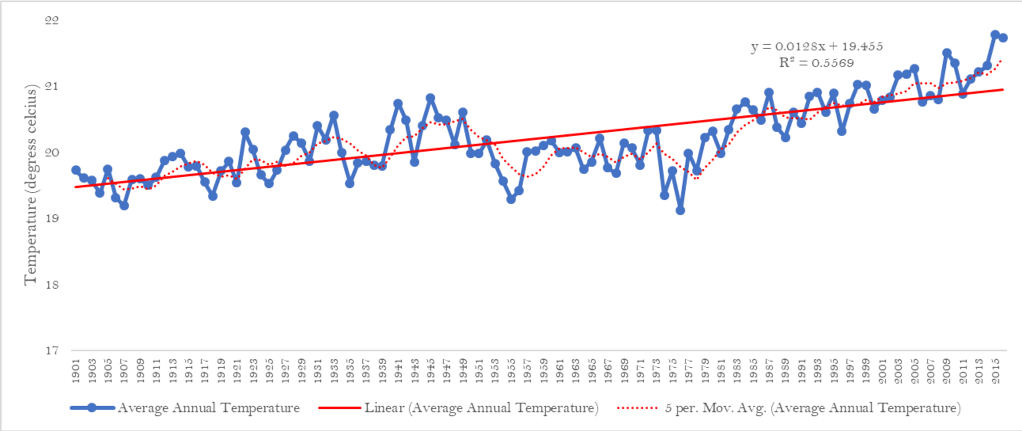


Figure 4.4: Historical trend in average annual temperature in Namibia (1901 - 2016)
Source: generated by the author using CRU dataset (2019)

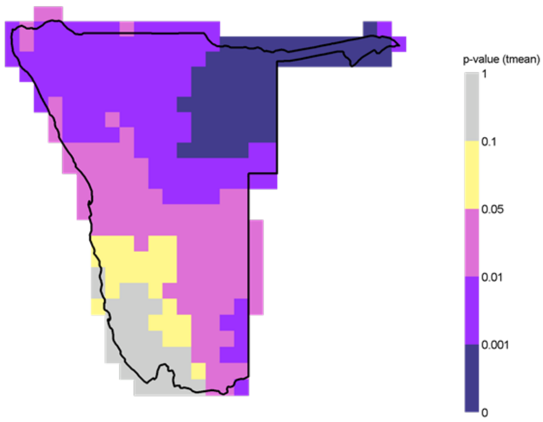


Figure 4.5 - Statistical confidence of temperature changes (1901 - 2016)
Areas with higher statistical confidence in change are in darker purple, and tan areas are marginally significant (0.05 - 0.10). Grey areas have low statistical confidence in change

Source: generated by the author using the CRU dataset (2019)

4.2.2.2. Precipitation (1901-2016)

Detecting trends in precipitation is typically more difficult than in temperature for countries with highly variable arid climates such as Namibia. This is because a single extreme rainfall event can contribute a significant proportion of the annual rainfall in some regions. Figure 4.6 spatially presents the rate of change of annual precipitation during the period 1901-2016. Figure 4.7 shows a plot of the average annual precipitation for Namibia. Figure 4.7 ignores the within-country variations to provide a rapid overview of changes in the average annual precipitation over the period 1901-2016.

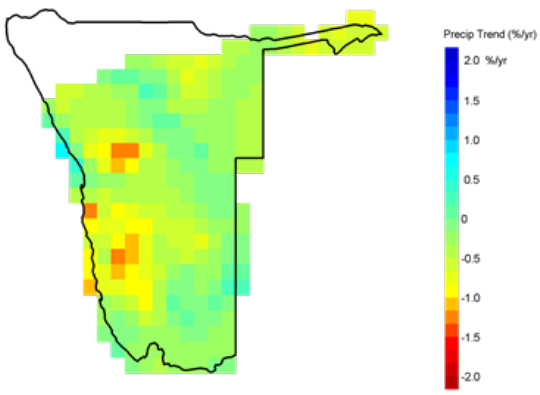


Figure 4.6 - Historical rate of change for precipitation, at 0.5 degree resolution (1901 - 2016)
Source: generated by the author using CRU dataset (2019)

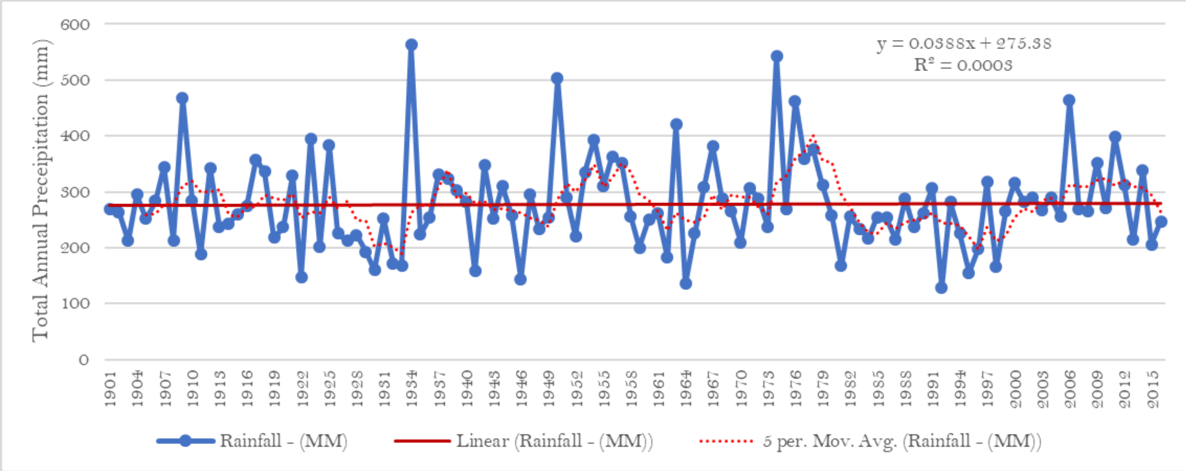


Figure 4.7 - Historical trend in annual precipitation in Namibia (1901 - 2016)

Source: generated by the author using CRU dataset (2019)

Unlike temperature (Figure 4.3 and Figure 4.4), there are no obvious trends in precipitation during the reference period (Figure 4.6 and Figure 4.7). The precipitation data analysis presented in Figure 4.6 and Figure 4.7 are consistent with those of Dirkx et al. (2008). Figure 4.7 shows a non-significant precipitation increase of about 0.039mm per year. It is important to interpret Figure 4.7 in conjunction with the statistical confidence provided in Figure 4.8, which clearly shows that the rate of change of precipitation has a low confidence. Furthermore, the precipitation trend shown in Figure 4.7 only explains 0.03 percent (the R^2 value of the trend) of the variation in precipitation over the reference period. Therefore, it is concluded with low confidence that there wasn't an obvious trend in the rate of precipitation change during the period 1901-2016. Thus, it is recommended that areas with low statistical confidence in the data analysis results should not be used for taking climate-related decisions.

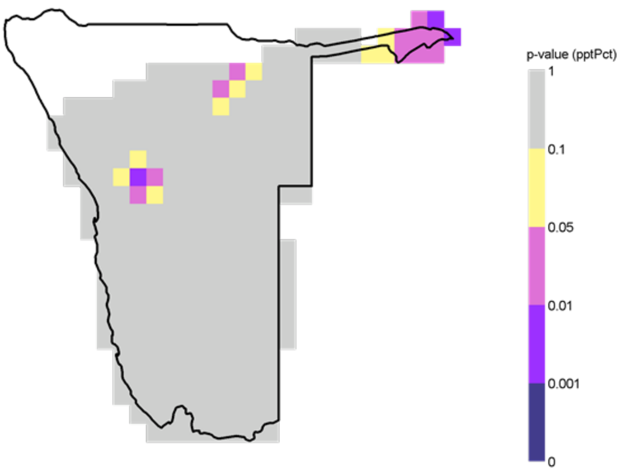


Figure 4.8 - Statistical confidence of precipitation changes (1901 - 2016)

Areas with higher statistical confidence in change are in darker purple, and tan areas are marginally significant (0.05 - 0.10). Grey areas have low statistical confidence in change

Source: generated by the author using CRU dataset (2019)

4.2.3. Climate Projections: Mid-century (2040-2069) and End-century (2070-2099)

Despite the considerable progress made in climate change science, uncertainty is still an issue when projecting climate at the global, regional, and national levels. Several issues constrain projections of climate. Uncertainty regarding future global GHG emissions; limitations in the understanding of the dynamics of global climatic systems; natural climatic variability displayed in the baseline data; uncertainty pertaining to the CO_2 'fertilization' effect on plants; and limitations in the downscaling techniques employed to produce RCMs from GCMs. The simulations at best, produce only a possible evolution of future climate systems.

For most parts of southern Africa, particularly the semi-arid regions, which includes Namibia, the uncertainty highlighted above is compounded by the restricted coverage with hydro-meteorological stations and the paucity of homogenous, long term, high-quality datasets. Ultimately, the uncertainties associated with climate change projections and lack of high-quality datasets hamper the construction of plausible climate models and constrain the reliable assessment of potential scenarios, vulnerability, and adaptation to climate change in the country (Warbuton & Schultze 2005; von Maltitz et al. 2005; Dirkx et al. 2008).

When making climate projections, several GCMs use global development storylines, i.e., the so-called Emission Scenarios, as inputs. Therefore, each Emission Scenario leads to a suite of possible futures and a plausible representation of future climate. The projections presented below are averages of statistically downscaled projections made by 35 GCMs.

4.2.3.1. Temperature

It is predicted with a high degree of certainty that Namibia can expect an increase in temperature at all localities, with the highest increase in the interior. Figure 4.9 and Figure 4.10 presents the expected deviations of annual mean temperature from the baseline (1981-2018) at mid-century and end-century respectively. The north-eastern parts of the country are expected to experience the highest increases in average annual temperature for both time horizons. It is projected that the mean annual temperature will increase by 2°C and 4°C relative to the baseline (1981-2018) by mid-century and end-century respectively, under the worst-case scenario (i.e., a2 Emission Scenario).

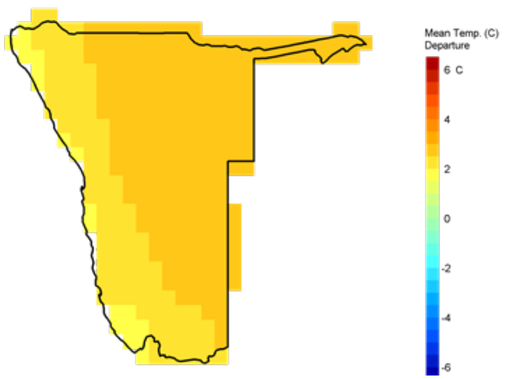


Figure 4.9 - Projected temperature change for mid-century (2045 - 2069) relative to the baseline period (1981 - 2018)

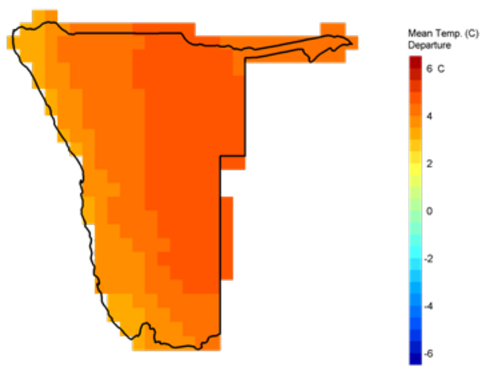


Figure 4.10 - Projected temperature change for end-century (2070-2099) relative to the baseline period (1981 - 2018)

4.2.3.2. Precipitation

There is greater uncertainty associated with the projection of precipitation compared to temperature. As a result of this, there is little agreement among the 35 GCMs on whether precipitation will decrease, remain the same or increase. However, the majority of the 35 GCMs predict that Namibia will become drier, that rainfall variability will likely increase, and that extreme events such as droughts and floods are likely to become more frequent and intense. Figure 4.11 and Figure 4.12 present the mean expected deviations of annual precipitation from the baseline (1981-2018) for mid-century and end-century respectively. In both cases, at least half of the models project an increase (blue areas), as well as a decrease (yellow to red areas). With regards to precipitation, mid-century, and end-century projections respectively show, with low confidence, a 7 percent and 14 percent reduction from the baseline period (1981-2018).

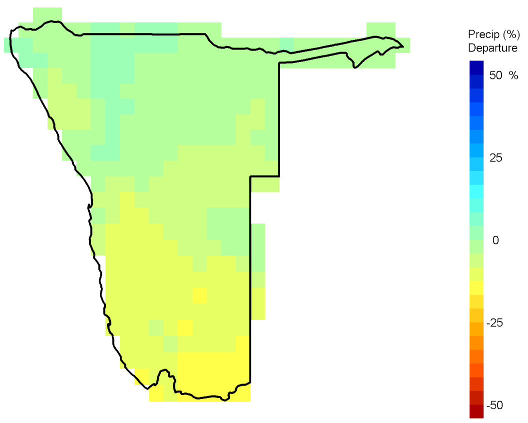


Figure 4.11 - Projected precipitation change for mid-century (2045-2069) relative to the baseline period (1981 - 2018)

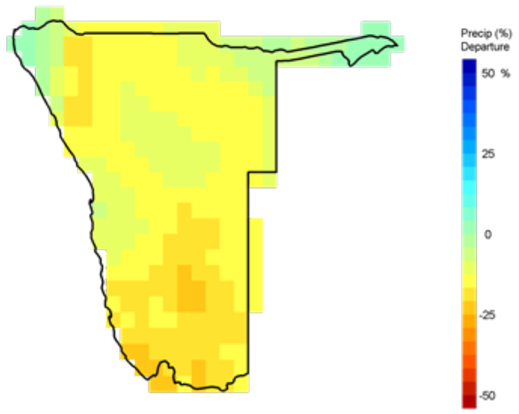


Figure 4.12 - Projected precipitation change for end-century (2070-2099) relative to the baseline period (1981 - 2018)

4.3 Vulnerability, adaptation and impact analysis

This section presents the current drivers of climate change vulnerability; analysis of the vulnerability and adaption options in key sectors; analysis of the observed and expected impacts of climate change; and concludes with key messages.

4.3.1. Current Drivers of Climate Change Vulnerability

Namibia is one of the climate change vulnerability 'hotspots' in the southern Africa region (ASSAR, 2019). The country's vulnerability stems from its climate, landscapes, socioeconomic and environmental characteristics (i.e., its geography). From a socioeconomic perspective, colonial legacy of apartheid has created persistent structural inequalities as well as skewed access to productive assets such as land. These inequalities and skewed access to productive assets coupled with poverty and unemployment levels reduces the ability/capacity of most Namibians to cope and mitigate the adverse impacts of climate change. Drought is common given Namibia's hot, dry climate and erratic rainfall. Localized water scarcity, desertification, and land degradation are all key drivers of climate change from an environmental perspective. Threats to the country's biodiversity include habitat destruction and uncontrolled development, forest clearing, overstocking, unsustainable harvesting of wild plants and animals, unequal resource distribution, fencing, and the fragmentation of protected areas (MET, 2010).

4.3.2. Vulnerability and Adaptation Analysis

Building on existing climate change vulnerability and adaptation knowledge, this section reviews, prioritizes and summarizes the most significant climate change risks and vulnerabilities for the sectors Agriculture, Water Resources, Coastal Zone, Health, Urban and Rural Settlements and Tourism. The key messages for each sector, in terms of vulnerabilities and adaptation, are summarised in Table 4.1.

To generate this information, a meta-analysis was done on a variety of literature, including grey literature on climate change vulnerability and adaptation, the focus being on publications post the NC3 and information not covered in the latter. The information characterizes each sector on the three core components of vulnerability, namely exposure, sensitivity, and adaptive capacity.

4.3.2.1. Agriculture

Agriculture is a key sector of the Namibian economy. It is not only the largest employer and also critical to livelihoods and food security. Over two-thirds of households practice subsistence cropping and pastoralism, mostly on communally-held lands. Agricultural production ranges from the intensive production of horticultural crops) to large-scale production of cereals, mainly maize and millet. Less than 10% of the land surface is used for crop production, while nearly 75% is used for livestock production.

Climate limitations are important in determining potential agricultural activities and suitability across the country. However, irrigation and conservation-tillage practices can overcome rainfall constraints, both in the small-scale and commercial subsectors. Irrigation for agricultural production is estimated to consume more than 60% of Namibia's surface water resources, as well as a significant fraction of extracted groundwater. This makes agriculture the primary water user in the country. As such, the management of water resources is a key focus area for adaptation in this sector.

Risks and Vulnerabilities

The agricultural sector is one of the most critical economic sectors in terms of potential impacts of climate change. Agricultural output is extremely sensitive to climatic conditions. Periodic droughts cause considerable stock losses and reduce grain production. The agriculture sector is impacted directly by changes in precipitation, temperature, and evaporation, and through secondary impacts, including disaster risk and health issues. The most significant climate change risks and vulnerabilities for the agricultural and forestry sectors include:

- Increasing temperatures and more variable precipitation across the country, likely to have significant impacts on a wide variety of crops and forestry products;
- Irrigation demands that are projected to increase due to higher temperatures;
- Spatial shifts in the optimum growing regions for field crops and forestry;
- Yields of rain-fed crops such as maize, sorghum, and millet negatively impacted. Millet, the staple for most of the population, is relatively drought resistant, particularly indigenous and improved regional varieties, but if effective soil moisture decreases in the future, then decreases in yield, and a greater inter-annual variability in yield, are likely;
- Increased temperatures will have serious implications on farm labour;
- Increased temperatures will negatively impact livestock production, particularly in the southern and central regions of the country;
- Increasing risk of floods and other extreme events impacting on crops, as well as potential impacts on related infrastructure and distribution networks;
- Increasing demands from other sectors and areas, particularly cities, will increase competition for scarce resources such as water and productive land;
- Climate change effects on plant and animal diseases and insect distribution could adversely affect crop yields and livestock production.

Adaptation

Climate change problems are superimposed upon the many other challenges and stressors that the agriculture sector already faces, such as environmental degradation, disease outbreaks, and higher input costs. To a certain extent, the sector is already adapting/coping with climate change (MET, 2015). Current/potential adaptation options and issues in the agriculture sector are:

- Adaptation strategies include the implementation of Climate Smart Agriculture, improved water management, improved monitoring and early warning, the development of knowledge and decision-support systems, and the development of new crop varieties and technologies to support farming;
- Data gaps include the implications of higher temperatures on livestock health; changes in the pest, weed and disease distribution; biophysical response of plantations to elevated temperatures and levels of CO_2;
- Barriers to adaptation include reduced extension service and a slow uptake of Climate Smart Agriculture and Conservation Agriculture techniques;

- Possible benefits of climate change include higher crop yield in those areas with increased precipitation and elevated levels of CO_2 as the latter being temperature- and rainfall-dependent; societal benefits of implementing conservation agriculture and efficient irrigation methods.

4.3.2.2. Coastal Zones

The Namibian coastline, on the Atlantic Ocean, is approximately 1,200 km long and consists of 78% sandy beaches, 16% rocky shores and 4% mixed sand and rocky shores. Lagoons back only 2% of the shore. There are four significant towns on the coast: Lüderitz, Walvis Bay (the only deep-water port), Swakopmund and Henties Bay. Tide gauge records from Lüderitz and other localities on the west coast of southern Africa over the last 30 years have revealed an estimated sea-level rise that is comparable with the global measurements (IPCC, 2014). The AR5 shows that, under the a2 GHG emissions scenario, global sea-level rise is estimated to be above those recorded in the mid-1990s (the baseline) by 6 - 25 cm in 2030; 10 - 65 cm by 2070; and 23 - 96 cm by 2100 (IPCC, 2015). Given the lack of natural and human-made protective infrastructure to storm surges, the coastal areas are highly vulnerable to sea-level rise.

Risks and Vulnerabilities

The most significant drivers of climate change risks and vulnerability that are of importance to coastal environments and fisheries are: modification of terrestrial climatic and hydrologic processes; change in coastal and oceanic circulation processes; ocean acidification; increased sea surface temperature; sea-level rise; increase in sea storminess; and changing wind systems. The observed/projected negative impacts on the coastal environment and fisheries as a result of the climate change risk and vulnerability drivers mentioned above are:

- The primary hazards to Namibia's coastal infrastructure related to the sea are direct wave impacts, coastal flooding and inundation, erosion and under-scouring (Theron et al., 2010). Rises in sea level, combined with rises in sea surface temperature, and an increase in storms, have the potential to inundate settlements, harbours, marine aquaculture farms and fish-processing plants close to the shoreline;
- The problem with sea level rise is not just the vertical rise but also its interaction with changing storm intensities and wind fields which produces sea conditions that will progressively overwhelm existing infrastructure. Higher sea levels will lead to smaller storm events being able to overtop existing storm protection structures. Therefore, given the economic importance of the coastline for tourism and as a recreation asset such as angling, sport fishing, seal colonies, bird watching, and historical sites, sea level rise will negatively impact the economy. Considering only topography, low-lying coastal towns such as Walvis Bay are more under threat by sea level rise than relatively elevated coastal towns such as Lüderitz, Swakopmund and Henties Bay;
- Given the anticipated increasing upwelling conditions in the future, surface waters around Namibia is expected to experience more frequent occurrence of low pH;
- All coastal fisheries are susceptible to increased sea storminess; small-scale artisanal ones even more so. A general increase in wind strength and the frequency and strength of storms and extreme weather events will make it more dangerous and difficult to catch fish and will also reduce the number of days for the boats to go out to sea.

Adaptation

The adaptation measures proposed for coastal zones can be classified broadly into "*no regrets*" and "*additional*" options that are proactively designed to counter sea-level rise. *No regrets* options are efforts that are undertaken even if climate change were not happening. In the context of sea-level rise, *no regrets* options available to Namibia include: enforcement of development restrictions within the coastal buffer zone; reduce the degradation of wetlands, estuaries, dune cordons and sandbars; integration of sea-level rise scenarios into future planning decisions; incorporate sea-level rise risks in disaster management strategies; and alleviate poverty and improve living conditions (MET, 2007).

On the other hand, *additional* options are new interventions or investments, additional to the business as usual and existing efforts, designed to improve wellbeing, maintain the environment, and ultimately counter sea-level rise. These options can be classified into physical, biological and institutional responses. Physical options are hard engineering techniques such as seawalls, groynes, detached breakwaters, and revetments. Biological options are more natural, less likely to produce adverse consequences and more cost-effective than most physical options. They include dune cordons, estuary and wetland rehabilitation, and kelp beds. Institutional options are policy or decision-making responses. Additional options include vulnerability mapping and risk communication, design and implementation of appropriate and effective legislation, establishment of early warning systems, research and monitoring and design of appropriate insurance products to address sea-level rise (MET, 2007).

4.3.2.3. Water Resources

Namibia relies on dams, ephemeral rivers and aquifers for its water supply. These water resources are supplemented to a limited extent by unconventional sources such as reclaimed water and desalination. The absence of perennial rivers in Namibia's interior means that the country is reliant on rainfall as its natural water source. The semi-arid climate over most of the country coupled with high evaporation rates make the country one with a net water deficit (mean annual rainfall minus potential evaporation), ranging from -4000 mm in the southeast to -1600 mm in the northeast. Furthermore, supply-side problems are compounded by the fact that total water demand is steadily increasing at a rate of about 3.5% per annum. Even in the absence of climate change, certain areas, especially the Khomas region, Windhoek in particular, are already facing absolute water scarcity with less than 1000 m^3 of available water per capita per year.

Risks and Vulnerabilities

The drivers of climate risks and vulnerabilities in the Namibian water sector are well known, namely:

- Escalating financial/economic costs of supplying adequate water to agriculture (mainly crop irrigation), mining/industry, commerce, and an expanding, urbanizing population.
- Increasing concentrations of pollution which threaten the quality of diminishing water supplies.
- Increasing water scarcity and competition with neighbouring countries for available water.
- Environmental damage resulting from the unsustainable removal of water from underground aquifers. In particular, damage to riparian vegetation and wetland ecosystems which provide essential ecological services including water purification, streamflow regulation and the recycling of aquatic nutrients.
- Increasing water demand and water pollution by irrigation schemes.
- An increase in transboundary issues with upstream users (including Lesotho and South Africa in the case of the Orange River Basin and Angola and Zambia in the case of the northern perennial rivers) and downstream users (Botswana in the case of the Okavango) that share Namibia's perennial rivers.

Adaptation

To ensure sustainable long-term access to water, and effectively manage and conserve the country's water resources with the uncertainty of climate change, the following adaptation options are relevant:

- Promote efficient water harvesting techniques in areas that will benefit from an increase in rainfall. These techniques include water harvesting and storage through the construction of dams and pans.

- Promote the management of inflow and outflow of water. The inflow and outflow of water should be managed into dams and reservoirs to store water for agriculture and livestock use or even for human consumption particularly when there is no water or during dry season.
- Promote the recycling and re-use of water. Cities and municipal areas should recycle and reuse their water. The projections revealed that there would be a shortage of water, hence a great need for recycling water to ensure that there is water security rather than relying on pipeline. For instance, Walvis Bay has been hit by lack of water since the pipeline that supplies water is damaged due to flood in Kuiseb River.
- Promote the use of desalination technologies to increase water supply. Desalination transforms seawater into drinking water. The reverse osmosis technology of desalination is also used to treat contaminated wastewater. However, desalination is an energy- and capital- intensive process.
- Promote flexibility in water use allocations and increase coverage of water supply and water treatment facilities across sectors, households, and individuals targeting both rural and urban communities at local, regional and national level.
- Promote and encourage integrated water resources management, including contingency planning for extreme events such as floods and droughts.
- Promote and encourage artificial recharge of groundwater in the arid and semi-arid environment.
- Construct new water facilities, infrastructure and promote alternative water access, e.g. desalinization and fog harvesting as well as optimizing the existing facilities. and
- Prevention of water pollution.

4.3.2.4. Health

Based on the 2016/17 Namibia Intercensal Demographic Survey and the 2006/07 National Demographic and Health survey, the main causes of death in children under five years are diarrhoea (42%), under-nutrition (40%), malaria (32%) and acute respiratory infections (30%), although it must be noted that multiple causes of death are frequent. All these causes of death have a strong environmental component linked to climate. The main causes of adult mortality are AIDS, tuberculosis, and malaria, and since these diseases often co-occur, it is difficult to establish the exact cause of death.

Risks and Vulnerabilities

Climate change is already compounding the causes of infant and adult mortality and this will exacerbate with climate change in the future. The following are the observed/projected climate change risks and vulnerabilities in the Health sector:

- Higher rainfall in areas that were previously not used to receive these amounts will increase populations of disease-carrying insects in these areas. A case in point is the mosquito carrying malaria. Previously, these mosquitoes were restricted to the north-central and north-eastern parts of Namibia, which received the most rainfall and floods. However, the recently observed trend is mosquitoes moving towards the central parts of the country. This trend can be attributed, among others, to open standing water which serves as habitats and breeding grounds for mosquitoes.
- Furthermore, flood incidences, whose frequency is increasing, are usually accompanied by outbreaks of water-borne diseases and infections, such as cholera and diarrhea.
- Higher temperatures in an area that already experiences very high temperatures are likely to not only increase mortality among the elderly, infants and others whose health is already poor, but also increase the incidences of disease epidemics that are linked to high temperature such as meningitis and heat strokes, especially among the elderly, infants and the sick. and
- Drought decreases the nutritional status, particularly of the rural population, and reduces the availability of clean water. Susceptibility to respiratory and gastrointestinal infections and other

water-borne diseases such as bilharzia increases, possibly in part due to vitamin A deficiencies that increase in frequency during drought periods. Increased drought in the future, in the absence of safe water provision and secure nutrition, would exacerbate these problems.

Adaptation

Adaptation needs and barriers in the Namibian health sector include:

- A lack of understanding of the linkages between climate and health in Namibia (e.g., quantitative link between high temperatures and mortality). Thus, the current impact of climate-related diseases is not quantified, nor is the vulnerability of communities to such risks. Without a better understanding of the current health burden, it is not possible to understand how climate-sensitive health risks will change in a changing climate. A quantitative vulnerability and risk assessment for the health sector should be performed. This will help to identify the most important health risks, as well as the most vulnerable populations or communities. Adaptation strategies can then be tailored for regions or communities based upon their risks and vulnerability.
- The sparse population distribution in Namibia makes the planning for health care infrastructure and staffing problematic. As a result, the ability of the health care system to respond to climate change-induced health problems is or will be constrained.
- Furthermore, distance is a key factor that impedes the accessibility and effectiveness of health care infrastructure, especially among the poor segments of the population. Maintenance of infrastructure, coordination of the state ambulance service, and specialist referrals are therefore often problematic.
- Decreasing the vulnerability of the sector to climate change depends on cross-sectoral cooperation and collaboration. All health risks can be mitigated or exacerbated by actions, policies, etc. by sectors outside of the health sector. Namibia does have many environmental and health policies and programs in place. However, there is a lack of formal and supported inter-sectoral linkages between health and the environment. and
- The Namibian health system is vulnerable to the state of health and disease burden of people from neighbouring countries. For example, the majority of malaria cases in Namibia are not from local transmission.

4.3.2.5. Cross-Cutting Climate Change Risks

There are several cross-cutting impacts between human settlements and other sectors, such as terrestrial ecosystems, tourism, and food security.

Terrestrial Ecosystems

Biodiversity of terrestrial ecosystems such as the Namib Desert are highly adapted to hot, dry conditions, and are partly buffered against climate change by the proximity of the Atlantic Ocean. The Succulent Karroo biome in the southwest, one of the world's 'global biodiversity hotspot,' is regarded as under high risk of ecosystem boundary shifts and local extinction under climate change scenarios. It is a diverse and unique biome occurring in an area of winter rainfall and hence is vulnerable to changes in the seasonality of rainfall projected by some of the climate change models. There are also many endemic plants with very restricted distributions along the escarpment that are regarded as highly vulnerable to climate change. The escarpment separates the arid deserts from the semi-arid savannas (MET, 2013).

Wetlands (including coastal lagoons and seasonal oshanas) occupy less than 5% of Namibia and are highly vulnerable to a decrease in water flow, whether caused by climate change or human development or both. Marine biodiversity off the Namibian coast declines from south to north, an anomaly, as generally biodiversity increases as one moves from the poles to the tropics. A southward movement of warm tropical waters would thus reduce marine biodiversity in Namibia. The large flocks of Palaearctic and resident sea- and shorebirds would be susceptible to changes in either climate or other marine resources through changes in food supply and availability of breeding sites. The impact would be compounded further by water flow reduction at river mouths (including the coastal Ramsar sites) under the combined pressure of increased human water demand and increased temperature and evaporation (MET, 2015).

Tourism

Namibia's tourism industry has undergone rapid growth since the late 1980s, with an average increase in international arrivals of 16% per year on average. This growth rate has made tourism the fastest-growing sector of the Namibian economy. Tourism in Namibia relies largely on the wildlife sector, and most of the tourists visiting Namibia are predominantly interested in seeing wildlife and beautiful landscapes. Changes in the quality of wildlife viewing, wildlife numbers and the vegetation as a result of climate change is expected to affect the demand for wildlife tourism, that is estimated to be as much as a 15 % reduction in tourism demand. Despite the climate change impacts mentioned above, the Namibian tourism sector is relative to climate change; this is because of the high contribution of landscapes to the visitor experience which will not be significantly impacted by climate change. Furthermore, the loss in tourism demand caused by changes in the quality of wildlife viewing and wildlife numbers is expected to be offset by increased interest and demand for other forms of tourism subsectors such as adventure tourism.

Food Security

Health goes hand-in-hand with food security. Climate change directly affects the production and distribution of food and reduced access to affordable, nutritious food will increase diet-related health problems such as malnutrition or obesity. Urban food security relies on linkages with rural areas, and the associated impacts on the agriculture sector at local and global levels that, in turn, impact on prices (Ruwoldt, 2013).

4.3.3. Observed Climate Change Impacts

The observed impacts of climate change on key sectors and systems in Namibia are comprehensively articulated in the NC1 MET (2001), NC2 (MET, 2007) and NC3 (MET, 2015) as well as other studies such as Midgley et. al. (2005) and Dirkx et al. (2008). However, apart from the changes in temperature and precipitation, periodic droughts and floods are well-known climate threats in Namibia. These two threats impact agriculture and food security, water availability and health, catalysing forest fires and undermining Namibia's already low climate resilience and adaptive capacities. Namibia has declared numerous disasters due to flooding and drought between 1930 and 2017. Per decade, the country has experienced an average of two major droughts and two devastating floods. Many years have had prolonged droughts while the severity and frequency of floods resulted in reduced year-on-year ability of rural households to recover and restore livelihoods. Hence, climate-related threats and disasters can significantly lower local-level resilience and adaptive capacities due to the loss of belongings, land capacity, and infrastructure.

4.3.4. Expected/Future Climate Change Impacts

Namibia's future vulnerability to climate change will be determined by the nature of the biophysical changes to which its population, economy and livelihoods are exposed, and by national and individual capacities to manage, recover from, and adapt to these changes. A recent study of expected climate change impacts in Namibia by the ASSAR project (ASSAR, 2019) analysed the implications of the 1.5°C, 2°C, 2.5°C, and 3°C global warming thresholds under the Paris Agreement for Namibia. Figure 4.13 presents the implications of the global warning thresholds on selected environmental and socioeconomic sectors in Namibia, i.e., climate, agriculture, water, health, and biodiversity. From the information presented in Figure 4.13, it is clear that crossing the 2°C, 2.5 °C and 3°C global warming thresholds would result in climate change impacts, that are worse than the global average.

According to the analysis in ASSAR (2019), 2°C global warming under the Paris Agreement has significant implications, for the country is expected to experience warmer and drier conditions at magnitudes greater than the global average. Even a 1.5°C increase in global temperature will have severe local impacts, negatively affecting the Agriculture, Water, Health, and Biodiversity sectors. For instance, if the ever-nearer threshold of 1.5°C global warming is crossed: the mean average temperature is expected to increase by 2°C; evaporation rates will increase by 10%; both livestock and cereal crop productivity are expected to decrease by 5%, and 30% of species will be lost. A summary of vulnerability and adaptation of the different socio-economic sectors is listed in Table 4.1.

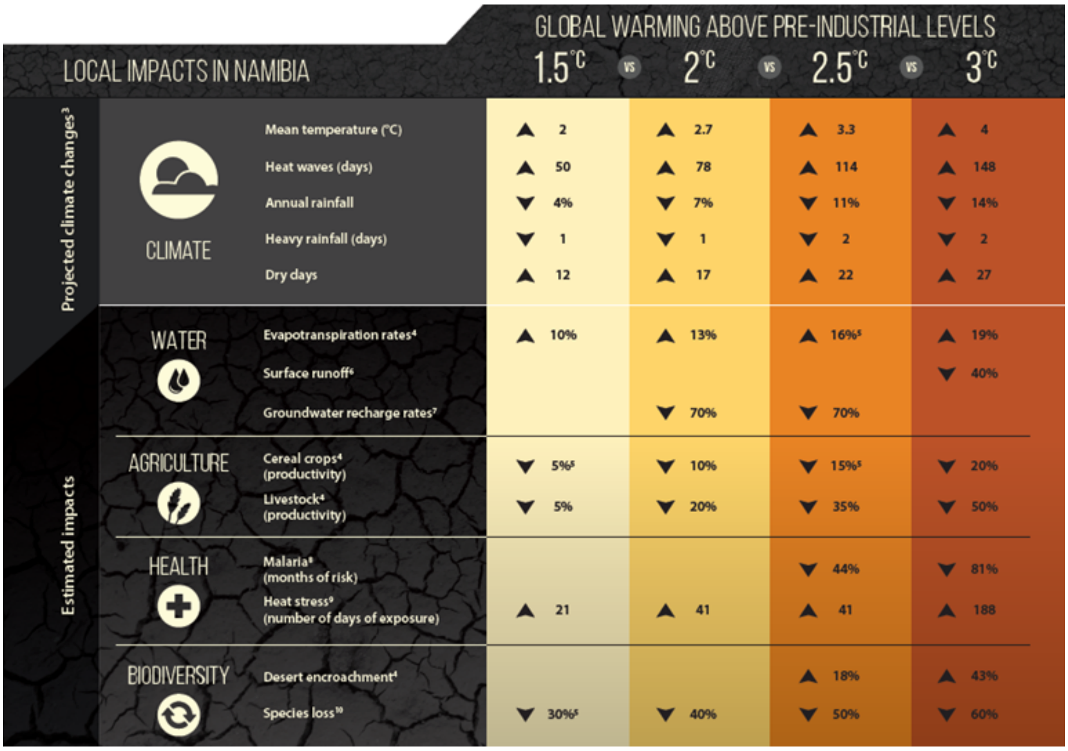


Figure 4.13 - Projected climate changes and impacts of global warming on Namibia

Source: ASSAR (2019)

Table 4.1 - Summary of the Vulnerability and Adaptation Assessment of key sectors in Namibia

Exposure Analysis (*climatic driver*)	**Sensitivity Analysis (*stressors*)**	**Impact Analysis (*adverse effects*)**	**Adaptation priorities (*actions required*)**
Sector: Agriculture			
• Reduction in rainfall • Changes in rainfall distribution • Increase in drought frequency • Increase in heatwaves	• Land use and change • Water stress • Invasive alien plants	• Reduction in productivity in the crop and livestock sectors • Increased pressure on water resources	• Conservation Agriculture • Climate-Smart Agriculture • Use of water-efficient Irrigation Systems or practices • Desalinization of seawater for irrigation purposes
• Sea level rise • Modification of terrestrial climatic and hydrologic processes • Change in coastal and oceanic circulation processes	• Direct wave impacts, coastal flooding and inundation, and erosion and under-scouring • Land-use change	• Intrusion of saltwater • Loss of or changes to coastal wetlands • Higher (ground)water levels and limited soil drainage	• Land use planning • Designation of flood areas/high-risk areas and development - free zones • Construction of dikes, groynes, bank protection, sea walls

Exposure Analysis (*climatic driver*)	Sensitivity Analysis (*stressors*)	Impact Analysis (*adverse effects*)	Adaptation priorities (*actions required*)
• Ocean acidification • Increased sea surface temperature • Increase in sea storminess • Changing wind systems		• Flooding of low-lying areas and resultant damage erosion of beaches and bluffs	• Beach nourishment, dune protection
• Reduction in rainfall • Increase in temperature • Increase in evaporation rate	• High water demand: current water usage already exceeds reliable yield • High levels of variability in rainfall from year to year, resulting in frequent droughts • Deteriorating water quality of major river systems, water storage reservoirs, and groundwater resources	• Increase in water demand from agriculture and settlements • Increased erosions and sedimentation of dams • Increase evaporation loss from dams • Affect biological and microbiological processes	• National water policies, plans, and funds mainstream climate change adaptation • Infrastructure development, operation, and maintenance • Groundwater needs to be protected by preventing groundwater degradation and unwise exploitation
Sector: Health			
• Drought frequency • Increase in temperature • Increase in heatwaves	• Quadruple burden of disease in Namibia and people from neighbouring countries • Poor housing, infrastructure, and service delivery • Change in the geographical distribution of diseases, e.g. Malaria might spread southward. New diseases might develop. • Water supply, agriculture, catastrophic events may have short- and long-term effects on the health of the population. It would be essential to include these contributing factors and their health impacts in the sensitivity analysis.	• A changing climate can have a myriad of impacts on the health sector • There is a lack of understanding on the linkages between climate and health in Namibia (e.g., quantitative link between high temperatures and mortality)	• Cross-sectoral cooperation and collaboration • Tailored Adaptation strategies to regions or communities based upon their risks and vulnerability • Measuring/monitoring the effects of climate change on health will be very important.
Sector: Tourism			
• Increase in temperature • Decrease in rainfall • Increase in heatwaves • Changes in wildfire	• Habitat and ecosystem fragmentation • Land-use change • Invasive alien plants	• Reduction in the quality wildlife and wildlife numbers • Reduction in nature-based tourism demand • Reduction in nature-based tourists	• Promotion of landscape-based tourism • Integrating Ecosystem-based Adaptation in Community Based Natural Resources Management (CBNRM) program • Promotion of adventure tourism

Exposure Analysis (*climatic driver*)	Sensitivity Analysis (*stressors*)	Impact Analysis (*adverse effects*)	Adaptation priorities (*actions required*)
Sector: Human Settlements			
• Increase in temperature • Reduction in rainfall • Increase in rainfall intensity • Increase in drought frequency	• Deficit in infrastructure and provision of services	• Different human settlement types and locations having varying vulnerabilities and capacities will experience the hazards • Informal settlements and their population being the most exposed	• DRM • Mainstreaming of no-regret interventions • Principals of water sensitive urban design (WSUD) and consideration for ecological infrastructure
Sector: Terrestrial Ecosystems			
• Rising temp • Temp extremes • Decrease/increase in rainfall amount • Rising carbon dioxide • Changes in wildfire	• Habitat fragmentation • Land-use change • Invasive alien plants	• Climate change will lead to changes across the biomes through the alteration of existing habitats, seasonal rainfall, species distribution, and changing ecosystems functioning. • Threats vary in importance between the biomes, increase over time, and increase with the level of GHG.	• Land use planning • Land management • Ecosystem-based adaptation • Mainstreaming of stewardship programs • Monitoring and evaluation

4.4 Vulnerability of human settlements

One of the core purposes of the vulnerability assessment is to collate, generate and disseminate high quality and relevant information that will allow policymakers and planners to make informed decisions on how they might prepare the country to climate change impacts at local, regional and national levels. There is a need for this response to be greatest or concentrated in areas (constituencies or settlements) that are likely to be the most hard-hit by climate change.

Namibia is characterized by widely divergent natural resources (soils, water), plant and animal life and ecosystems, farming and other land-use systems, social systems (including population demographics) and economic strengths and weaknesses. Assessing the vulnerability of Namibia to climate change must consider these spatial differences in an evidence-based and integrated manner. For example, arid environments are not necessarily vulnerable if social and economic factors are strong, whereas climatically conducive environments can be highly sensitive to rapidly increasing population pressures and detrimental land management, rendering them vulnerable to climate change. Adaptation planning should be as spatially explicit as possible, thus ensuring that the focus is geared on natural and human systems most in need of strengthening.

It is against this background that this section is set out to explore where current climate stressors (mainly changes in temperature and precipitation) have the greatest impact within Namibia, and how the adaptive capacity shapes the vulnerability of communities. The goal is to identify constituencies (i.e., the unit that is used to analyse the vulnerability of human settlements) that are relatively more vulnerable to climate change impacts. This is done to make adaptation planning spatially explicit, thus ensuring that the focus is emphasized on constituencies mostly in need of strengthening in terms of resilience building.

The section achieves the purpose mentioned above by using an index-based approach in the assessment of the vulnerability of constituencies across Namibia to climate change. The index-based approach is conceptually and theoretically framed within the context of the IPCC definition of vulnerability, that is vulnerability is a function of impact (exposure and sensitivity) and adaptive capacity.

The steps adopted within the index-based approach are.

- Description of the approach and methods used in the assessment of the vulnerability of constituencies to the impacts of climate change.
- Assessment of the exposure of constituencies to climate-related stressors.
- Presentation of the sensitivity of constituencies to climate-related stressors.
- The adaptive capacity of constituencies to climate-related stressors.
- The vulnerability of constituencies to the potential impacts of climate change.
- Summary of the key findings and recommendations.

4.4.1. Vulnerability Assessment Approach and Methods

The vulnerability to climate change of constituencies is assessed using an index-based approach (Box 4.1) under the IPCC framework, which requires the measurement of *exposure* and *sensitivity* to the climate change risk factors, together responsible for the *potential impact* of climate change risk factors, and the capacity to manage and respond to those risks (i.e., adaptive capacity). Hence, exposure, sensitivity and adaptative capacity are the core elements of vulnerability to climate change (Figure 4.14). These elements are measured/quantified from the perspective of a specific human system, geographic area, sector, etc.

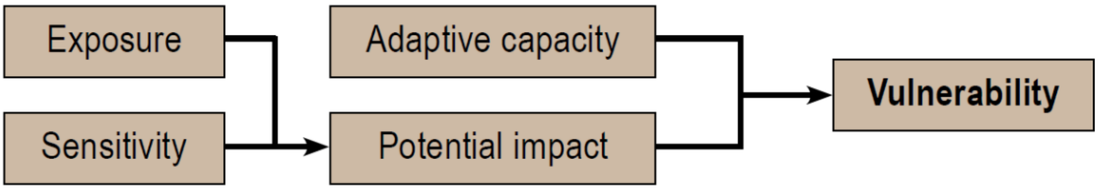


Figure 4.14 - Vulnerability and its components

A four-staged assessment framework was used in the assessment of the vulnerability of constituencies to climate change (Table 4.2). The description of the tasks, methods, and outputs of the assessment framework is presented in Table 4.2. As shown in Table 4.2, the assessment framework had four tasks, that is, measurement of exposure, sensitivity, adaptive capacity and vulnerability of constituencies to climate-related risk factors.

Box 4.1 - Index-based Approaches to Vulnerability Assessments

During the last three decades, various approaches to climate change vulnerability assessment have emerged. Fussel and Klein (2006) and FAO (2018), among others, provided an anointed bibliography of common approaches to climate change vulnerability assessment. Among the various vulnerability assessment methods, index-based approaches have gained prominence recently because of their ability to produce empirical outputs across various spatial scales as well as their ability to communicate varying degrees of vulnerability magnitudes decade (Fussel, 2009; Guillaumont et al., 2015; Miola et al. 2015).

Index-based methodologies tend to incorporate biophysical and socio-economic modeling and display vulnerability spatially through mapping. However, the output is limited by the subjective nature of selecting indicators, and by the difficulty in testing and validating the metrics used. Research has also found that these maps can make stakeholders feel over-confident, creating the impression that there is sufficient information when the method might fail to encapsulate several factors, such as spatial and temporal drivers of structural inequalities (Schroter, 2005).

Despite the limitations associated with index-based approaches, they are still gaining prominence in climate change science as a preferred method for measuring and communicating vulnerability at global, regional, and local levels. The increasing popularity of index-based approaches can be attributed to their ability to generate local level vulnerability

Box 4.1 - Index-based Approaches to Vulnerability Assessments
information that can inform local-level adaptation actions. Research shows that adaptation actions that informed by local-level vulnerability information tend to be more effective than adaptation actions informed by global, national and regional vulnerabilities. Namibia is a good case for using an index-based approach to measure climate change vulnerability. High-resolution climate data (i.e., drought, high temperature, low precipitation, floods, etc.) and socioeconomic data and indicators at constituency levels are available in Namibia. Climate data (trend and projections) at high spatial resolution (up to 0.25 degrees grid squares), for Namibia, is available and can be obtained freely from several Climate Change Data Portals. Namibia regularly collects socioeconomic data at constituency levels. For instance, the National Household Income and Expenditure Survey (NHIES), which contains representative socioeconomic data at constituency level, is collected every five years.

The assessment framework uses standardization techniques to measure exposure, sensitivity and adaptive capacity empirically, and principal component analysis (PCA) to measure vulnerability. The outputs of the assessment framework are four indices, that is, exposure index, sensitivity index, adaptive capacity index and vulnerability index (hereafter referred to as the Namibia Climate Change Vulnerability Index (NCCVI). Detail descriptions of the stages, tasks, methods, and outputs of the assessment framework are given in the sections below.

Table 4.2 - Vulnerability Assessment Framework

Stages/Tasks	Methods	Outputs
1. Measure the exposure of constituencies	Standardization	Exposure index
2. Measure the sensitivity of constituencies	Standardization	Sensitivity index
3. Measure the adaptive capacity of constituencies	Standardization	Adaptive Capacity index
4. Measure the vulnerability of constituencies	PCA	NCCVI

Initially, before the implementation of the assessment framework (Table 4.2) the identification and selection of variables/indicators to be used as proxy measures of exposure, sensitivity, and adaptive capacity were done. The identification of variables was informed by a rigorous review of relevant climate change literature (i.e., those that used index-based approaches) to identify variables that are widely used as proxy measures of exposure, sensitivity, and adaptive capacity. The selection or inclusion of a variable into the assessment framework was primarily based on the availability of reliable and valid data. Variables for which data was not available or partially available (i.e., available only for some constituencies, and missing for other constituencies) were excluded. Only variables for which data was available for all the 122 constituencies in Namibia were included in the assessment framework.

From the rigorous literature review and selection conditions described above, a total of thirty (30) variables were included in the Assessment Framework (Table 4.3). The definition and measurement description of the selected variables, the mapping of the selected variables to the three domains of vulnerability (i.e., *exposure, sensitivity* and *adaptive capacity*), and the data sources for the variables are also presented in Table 4.3. Variables that are mapped to the *exposure domain* are those that are related to the climate attributes of constituencies. The *sensitivity domain* variables capture the socioeconomic attributes of constituencies. And finally, the *adaptive capacity domain* variables capture the level/degree of multiple deprivation (MD)[3] in constituencies.

[3] Multiple deprivation (MD) is a concept is that is used measure the level of unmet needs, that is, material, education, employment, health, housing and services – in a given area.

Furthermore, it is obvious from the variables presented in Table 4.3 that they have different units and scale of measurement. To facilitate the construction of the exposure, sensitivity, adaptive capacity, and vulnerability indices, variable data were transformed to make them dimensionless and have a uniform scale. The transformation of the variable data was achieved using two data transformation techniques, namely the standardization and positive-censoring techniques.

Standardization was used to make the variables dimensionless. The following equation represents the formula that was used to standardize the variables:

$$\bar{x}_i = \frac{x_i - \mu}{\sigma} \ldots \ldots (1)$$

Where: $\bar{x}_i$ is the standardized variable value (e.g., temperature value) for constituency *i*; x_i is the unstandardized variable (e.g., temperature value) for constituency *i*; μ is the mean of variable x for all the constituencies, and σ is the standard deviation of variable x for all the constituencies.

The standardization technique (i.e., equation 1) generates a series of values, what is technically referred to as "normalized anomalies" or "z-scores." These "z-scores" are dimensionless and contain the same information as the original data. Although the generated "z-scores" are dimensionless, their measurement scale ranges between negative infinity to positive infinity. The index generation technique that was used in this study requires the use of positive values only. Therefore, a positive-censoring technique was used to transform the standardized variables (i.e., the "z-scores") so that they are positive and their scale of measurement ranges from 0 to 1. The 'positive-censoring' was done using the equation below (equation 2). Equation 2 generates a series of positive-censored z-scores that have a scale of measurement that ranges between 0 and 1, and contain the same information as the original proxy variable

$$SI\ \bar{x}_i = \left(\frac{\bar{x}_i - min\bar{x}_i}{max\ \bar{x}_i - \min \bar{x}_i}\right) \ldots \ldots (2)$$

Where: $SI\ \bar{x}_i$ is the positive-censored z-score; $\bar{x}_i$ is the z-score; $min\bar{x}_i$ is the minimum z-score value in the generated series of z-scores; and $max\ \bar{x}_i$ is the maximum z-score value in the generated series of z-scores.

Table 4.3 - Namibia Climate Change Vulnerability Index:
Description of variables/variable transformation/data sources

EXPOSURE DOMAIN **Exposure domain variables measure the climate attributes of constituencies, that is, character, magnitude, and rate of change and variation in the climate in the constituency.**		
Variables [Identification]	**Variable definition**	**Variable measurement**
Drought ***[E01] – Source:*** Atlas of Namibia (Mendelsohn *et al*., 2009) and own estimation	The variable measures the exposure of a constituency conceptualized as the frequency of drought events during the period 1949-2018.	The variable is measured as the probability of drought events during the period 1949-2018. The probability was estimated as the number of years with reported drought events divided by the total number of years during the reference period (89).
Flood ***[E02] – Source:*** Atlas of Namibia (Mendelsohn *et al*, 2009) and own estimation	The variable measures the exposure of a constituency as the frequency of flood events during the period 1949 to 2018.	The variable is measured as the probability of flood events during the period 1949-2018. The probability was estimated as the number of years with reported flood events divided by the total number of years during the reference period (89).
Temperature ***[E03] – Source:*** Fifth Assessment Report of the IPCC (data downloaded from (http://www.climatewizard.org).	The variable measures the exposure of a constituency as the variation (variance) in annual air temperature.	The variable measured as the average variance of annual air temperature during the period 1901-2018. The estimated average variance was normalized such that it ranges between 0 and 1.

Precipitation ***[E04]***	The variable measures the exposure of a constituency as the variation (variance) in annual precipitation.	The variable measured as the average variance of annual precipitation during the period 1901-2018. The estimated average variance was normalized such that it ranges between 0 and 1.
Water balance ***[E05]***	The variable measures the exposure of a constituency as the variation (variance) of the annual water deficit.	The variable measured as the average variance of annual water deficit during the period 1901-2018. The estimated average variance was normalized such that it ranges between 0 and 1.
SENSITIVITY DOMAIN **Sensitivity domain variables measure the degree to which a constituency is adversely by a given climate change exposure. Sensitivity captures the socioeconomic attributes of constituencies.** (Source: 2016 National Household Income and Expenditure Survey (NSA, 2016))		
Variables [Identification]	**Variable definition**	**Variable measurement**
Vulnerable livelihoods ***[S01]***	The variable measures the sensitivity as the number of households with vulnerable livelihoods sources (i.e., subsistence crop and livestock farming).	The variable is measured as the number of households with vulnerable livelihoods in a constituency expressed as a proportion of the total number of households with vulnerable livelihoods in Namibia.
Low Income Households ***[S02]***	The variable measures sensitivity as low-income households conceptualized as households with annual income in the lowest twenty-fifth percentile.	The variable is measured as the number of low-income households in a constituency expressed as a proportion of the total number of low-income households in Namibia.
Vulnerable Demographics ***[S03]***	The variable measures sensitivity as the vulnerable demographics conceptualized as the elderly (>65 years) and infants (<5 years).	The variable is measured as the number of vulnerable demographics in a constituency expressed as a proportion of the total number of vulnerable demographics in Namibia.
Population ***[S04]***	The variable measures sensitivity as the number of people in the constituency that might be exposed to the climatic hazards.	The variable is measured as the number of people living in the constituency expressed as a proportion of the total population in Namibia.
Food insecurity ***[S05]***	The variable measures sensitivity as the number of food-insecure households, that is, households that reported to have had insufficient food.	The variable is measured as the number of food-insecure households in the constituency expressed as a proportion of the total number of food-insecure households.
Undiversified income in agricultural households ***[S06]***	The variable measures sensitivity as the number of agricultural households with undiversified income sources, that is, households whose main source of income is agriculture only.	The variable is measured as the number of households with undiversified income sources in the constituency expressed as a proportion of the total number of agricultural households with undiversified income sources.
Child head households ***[07]***	The variable measures sensitivity as the number of child-headed households.	The variable is measured as the number of child-headed households in the constituency expressed as a proportion of the total number of child-headed households in Namibia.
Poor households ***[08]***	The variable measures the sensitivity of a constituency as the number household below the poverty line of N$520.8/month//person.	The variable is measured as the number of households below the poverty line in the constituency expressed as a proportion of the total number of households below the poverty line in Namibia.
Disabilities ***[S09]***	The variable measures the sensitivity of a constituency as the number of persons with disabilities	The variable is measured as the number of disabled persons in the constituency expressed as a proportion of the total number of disabled persons in Namibia.
Unprotected Water Sources ***[S10]***	The variable measures the sensitivity of a constituency as the number of households whose main source of drinking water is from unprotected sources.	The variable is measured as the number of households using unprotected drinking water sources expressed as a proportion of the total number of households with unprotected drinking water sources.

ADAPTIVE CAPACITY DOMAIN **Variables in the Adaptive Capacity domain measures the ability of the constituency to cope/moderate the climate change impacts (exposure and sensitivity).** (Source: 2016 National Household Income and Expenditure Survey (NSA, 2016))		
Variables [Identification]	**Variable definition**	**Variable measurement**
Material Deprivation ***[A01]***	The variable measures the adaptive capacity of a constituency using *material deprivation* conceptualized as the number of households who do not have access to a television, radio, telephone (landline) or cell (i.e., these assets are regarded as basic possessions that most households have in Namibia).	The variable is measured as the number of material deprived households in a constituency expressed as a proportion of the total number of material deprived households in Namibia.
Employment Deprivation ***[A02]***	The variable measures the adaptive capacity of a constituency using *employment deprivation* conceptualized as the number of economically activity persons (aged 15 years to 59 years inclusive) that are not employed.	The variable is measured as the number of employment deprived persons in a constituency expressed as a proportion of the total number of employment deprived persons in Namibia.
Health Deprivation ***[A03]***	The variable measures the adaptive capacity of a constituency using *health deprivation* conceptualized as deprived access to a medical facility or service, that is, persons who did not access a medical facility or received medical services due to affordability, travel costs, no doctor/nurse, no proper service and religious reasons.	The variable is measured as the number of health deprived persons in a constituency expressed as a proportion of the total number of health deprived persons in Namibia.
Education Deprivation ***[A04]***	The variable measures the adaptive capacity of a constituency using *education deprivation* conceptualized as the number of people aged between 15 to 59 years (inclusive) with no formal schooling and illiterate (can neither read nor write).	The variable is measured as the number of persons with education deprivation, in a constituency expressed as a proportion of the total number of persons with education deprivation in Namibia.
Housing Deprivation ***[A05]***	The variable measures the adaptive capacity of a constituency using *housing deprivation* conceptualized as improvised housing units (i.e., shacks).	The variable is measured as the number of persons with housing deprivation in the constituency expressed as a proportion of the total number of persons with housing deprivation in Namibia.
Service Deprivation ***[A06]***	The variable measures the adaptive capacity of a constituency using service deprivation conceptualized as households without electricity/solar power for lighting or proper toilet.	The variable is measured as the number of persons with service deprivation in the constituency expressed as a proportion of the total number of persons with service deprivation in Namibia.

4.4.2. The Exposure of Constituencies

The first stage of the vulnerability assessment framework involves the measurement of the exposure of constituencies to climate-related risk factors. Exposure measures the climate-related attributes of constituencies, that is the *character, magnitude, and rate of change* and *variation* in the climate. Exposure variables adopted were variance in temperature, precipitation, and water balance during the period 1901-2018, and the probability of flood and drought events during the period 1949-2018 (Table 4.3). The variables were transformed based on equations 1 and 2.

To generate the exposure index, all the transformed variables under the exposure domain were summed up at the constituency level. Since the exposure index shows the extent to which a constituency is exposed to climate-related risks/threats, the larger the value of the index, the higher the exposure. For presentation purposes, constituencies were classified into five exposure categories: Very High, High, Medium, Low or Very Low to climate change risks/threats. To classify the constituencies into the exposure categories mentioned above, constituencies were ranked in descending order using the computed exposure index. The first 20 constituencies were classified under Very High exposure, the next 25 under High exposure, and so on, and the last 25 constituencies under Very Low exposure. The ranking of all constituencies in Namibia based on their exposure index values is presented in Appendix A.1.

Based on the computed *exposure index*, Figure 4.15 spatially shows the exposure of constituencies across Namibia to climate-related risks/threats. Constituencies that are most exposed to climate-related risks (as defined in this study) are those that have a dark-red shading. Constituencies that are least exposed to climate-related risks/threats are those with a light-yellow shading. To show 'exposure hotspots' in Namibia, constituencies that are most exposed to climate-related risks, Figure 4.15 has been refined to give Figure 4.16, which only shows constituencies with an exposure index value ranked High to Very High. The mapping of all the constituencies based on their degree of exposure to climate risks is shown in Appendix B.1.

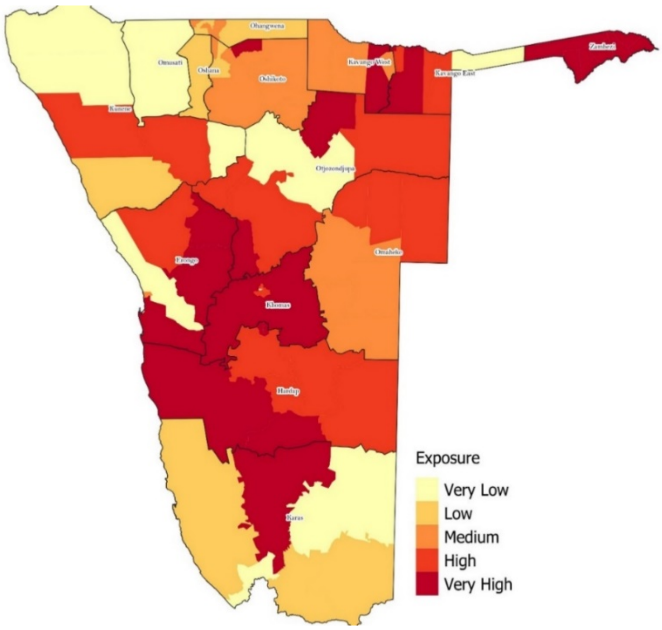


Figure 4.15 - The Exposure of Constituencies to Climate-related risks

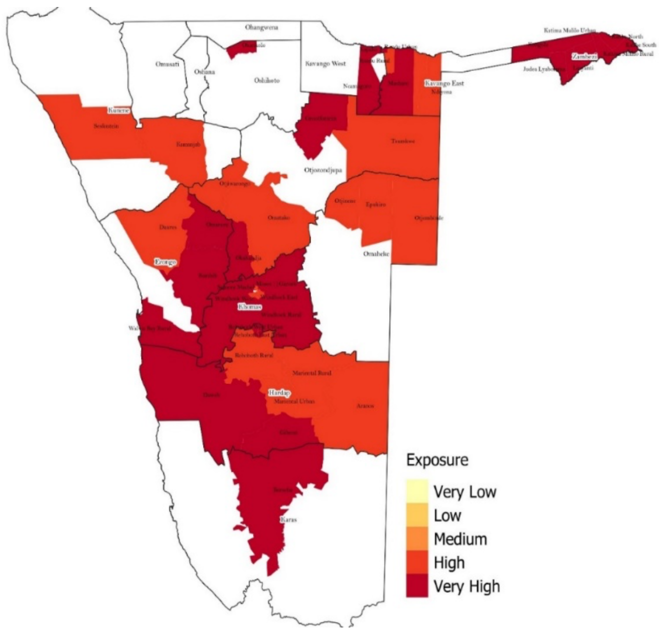


Figure 4.16 - Exposure Hot Spots Map (constituencies most exposed to climate-related risks)

The distribution of constituencies across the five quantiles of the *exposure index* and by administrative region is shown in Figure 4.17. Based on this distribution, constituencies that are highly exposed to climate risks are those in the Zambezi region followed by the Kavango East and West regions. On the other hand, all thirteen constituencies in the Omusati region are relatively less exposed to climate risk. Generally, it seems (based on Figure 4.15 and Figure 4.16) that constituencies in the central parts of the country are the most highly exposed to climate-related risks relative to other parts of the country.

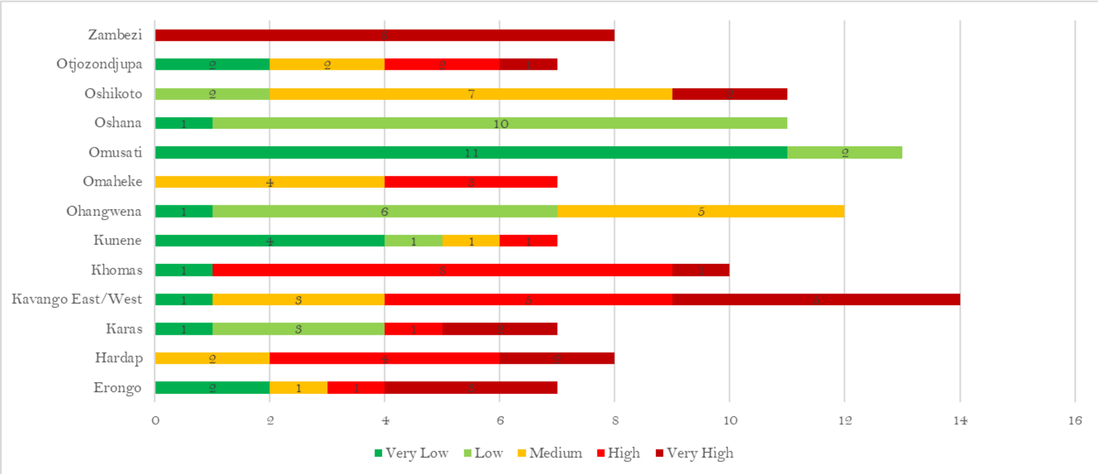


Figure 4.17 - Distribution of constituencies by exposure index categories and by administrative region

Knowing the key driver(s) or source(s) of climate change risks across the constituencies is critical for designing focused adaptation actions. In this study, the key drivers of climate risk were identified by analysing the contribution of each variable to the overall exposure index (Figure 4.18). Out of the 122 constituencies, temperature was found to be the highest contributor to climate change risks (50 constituencies) followed by drought (39). Based on these results, actions targeted at moderating the effects of changes in temperature and coping with drought are crucial for adaptation in most constituencies.

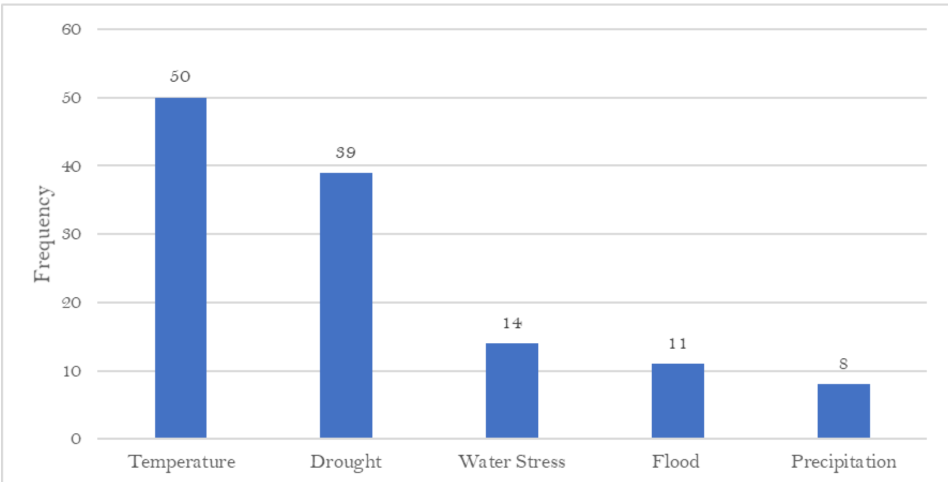


Figure 4.18 - Drivers of climate-risk in constituencies

4.4.3. The Sensitivity of Constituencies

The second stage of the vulnerability assessment framework involved the measurement of the sensitivity of constituencies to climate change exposure. Sensitivity measures the *degree to which a system is adversely or beneficially affected by climate-related risk factors*. Sensitivity is typically shaped by the natural/physical and socioeconomic attributes of the system which is the constituency in this case. Physical/natural attributes include topography, soil type, land degradation, land cover type, etc. Socioeconomic attributes include human/economic and social activities which affect the physical constitution of a system, such as tillage systems, water management, resource depletion, population pressure, demographics, etc. Societal factors such as population density and demographic composition should only be regarded as sensitivities if they contribute directly to a specific climate change impact.

For this study, only the adverse component of sensitivity was included in the measurement. The beneficial component of sensitivity was not included in the measurement because most climate change impacts in Namibia are generally negative. Therefore, sensitivity in this study measures the *degree to which a constituency is adversely affected by climate-related risk factors*. The climate-related risk factors referred to here are those described in the exposure domain. The variables that are used for measuring sensitivity in this study are primarily those that capture the socioeconomic attributes of the constituency (Table 4.3). The natural/physical attributes of the constituencies were not covered due to the absence of an exhaustive set of appropriate data to cover all constituencies in a comparable manner.

The sensitivity index was computed by summing up all the values of the standardized variables in the sensitivity domain (Table 4.3) at the constituency level. Like the exposure index, a larger value indicates a high sensitivity. Furthermore, constituencies with a high sensitivity are said to be less resilient to climate change exposure. On the other hand, constituencies with low sensitivity are said to be more resilient to climate change exposure.

Based on the computed *sensitivity indices*, Figure 4.19 and Figure 4.20 spatially show the sensitivities of constituencies to climate change exposure. Like the exposure index, the sensitivity index is also presented based on a five-category ordinal scale. The constituencies in a dark-red shading are relatively more sensitive (less resilient) to climate change exposure compared to those in a yellow shading which are less sensitive (more resilient) to climate change exposure. Figure 4.20 is a further refinement of Figure 4.19, and only shows the *sensitive hot spots*. The ranking of constituencies based on the computed sensitivity index is given in Appendix A.2.

From the 'sensitivity' and 'sensitivity hot spot' maps (Figure 4.19 and Figure 4.20), a pattern of sensitivity across Namibia is discernible. Generally, constituencies in the southern part of the country were found to be more resilient as opposed to the northern regions.

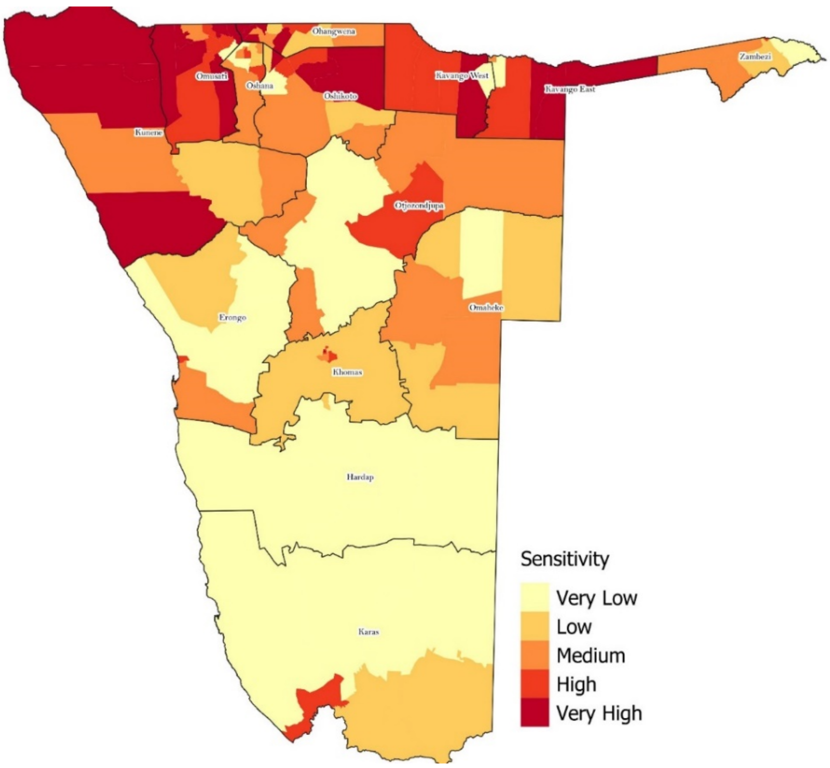


Figure 4.19 - The Sensitivity of Constituencies to climate change exposure

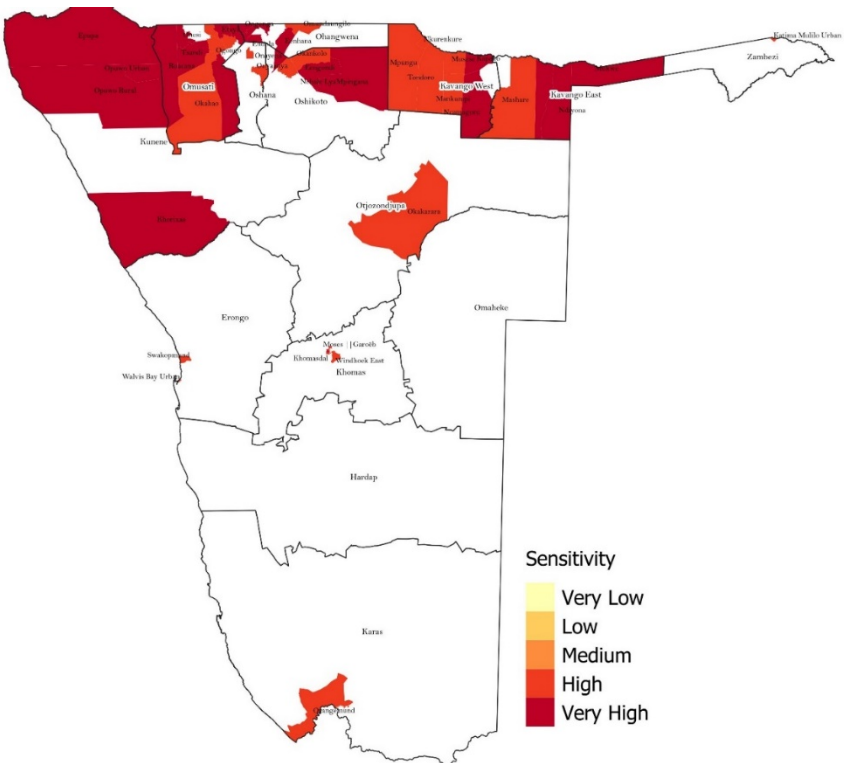


Figure 4.20 - Sensitivity Hot Spots Map

The regional distribution of constituencies across the categories of sensitivity index is shown in Figure 4.21. The complete mapping of all the constituencies to the five categories of the sensitivity index is given in Appendix B.2.

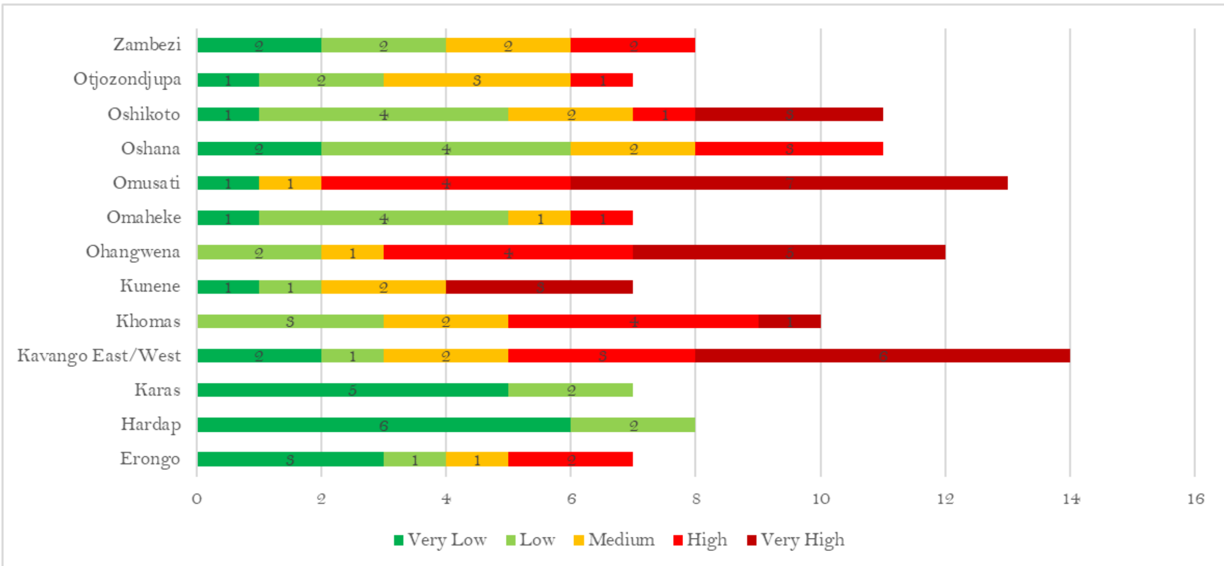


Figure 4.21 - Distribution of constituencies by sensitivity index categories and by administrative region

The key drivers of sensitivity in constituencies across Namibia is presented in Figure 4.22. Food insecurity, child-headed households, and vulnerable livelihoods were found to be the key drivers of sensitivity. The identified drivers are critical for the design and implementation of climate change adaptation actions in Namibia. For instance, enhancing/improving food security is a critical adaptation action for building the resilience to climate change risks/threats in constituencies in the northern parts of the country. Furthermore, population (or population density) a key parameter used in the prioritization of climate change adaptation investment in Namibia was not found to be a driver of sensitivity in any of the 122 constituencies in Namibia.

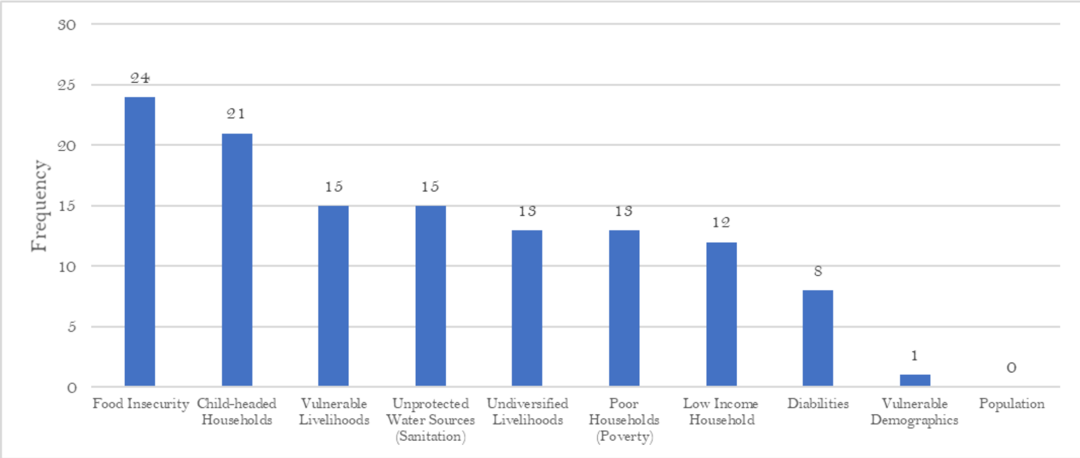


Figure 4.22 - The drivers of sensitivity to climate change exposure in constituencies

4.4.4. The Adaptive Capacity of Constituencies

The third stage of the assessment framework consisted in measuring the adaptive capacity of constituencies. That is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. As a result, the adaptive capacity is a set of factors that determine the capacity of a constituency or system to generate and implement adaptation measures. These factors relate largely to available resources of human systems and their socio-economic, structural, institutional and technological characteristics and capacities. As such, factors under the adaptive capacity domain tend to overlap with those in the sensitivity domain.

To avoid the overlap of the adaptive capacity domain with the sensitivity domain, variables that were used in the former only captured the institutional and technological attributes of constituencies. Furthermore, the study conceptualized adaptive capacity using the concept of Multiple Deprivation which is a measure of the level of unmet needs in terms of material, education, employment, health, housing, and services in each constituency. The spatial patterns and distribution of deprivations are not random, but outcomes of ineffective social, political, and institutional processes.

Multiple Deprivation is particularly important in Namibia because of the spatial legacy of apartheid that has resulted in the spatial concentration of poor Namibians in certain localities. In urban areas, poor Namibians tend to reside either in informal settlements around cities or towns. Whereas in rural areas, poor Namibians are confined to communal areas, formerly known as homelands, created in colonial times. The use of the Multiple Deprivations concept as a measure of adaptive capacity captures the political and institutional dynamics in constituencies across Namibia. The level of deprivations (unmet needs) can be seen as a measure of the strength or weakness of political power and/or institutional capacities in constituencies to guarantee financial resources and other services that could support climate change adaptation such as access to information, education, employment, and health services, *inter alia*.

Constituencies with high deprivation are conceptualized as those with weak political power or inadequate institutional capacity to lobby for or provide services that could support climate change adaptation. On the other hand, constituencies with low deprivations have strong political power or adequate institutional capacity to lobby for or provide services that could support climate change adaptation. It, therefore, follows that constituencies with low deprivations are expected to have high adaptive capacity, while those high deprivation are expected to have low adaptive capacity.

The variables that were used to capture Multiple Deprivations across constituencies in Namibia are presented in Table 4.3. The study empirically computed the *adaptive capacity index* by summing, at the constituency level, the values of all the standardized variables under the adaptive capacity domain (see Table 4.3). A larger *adaptive capacity index* value indicates *high deprivation*, which in turn implies low

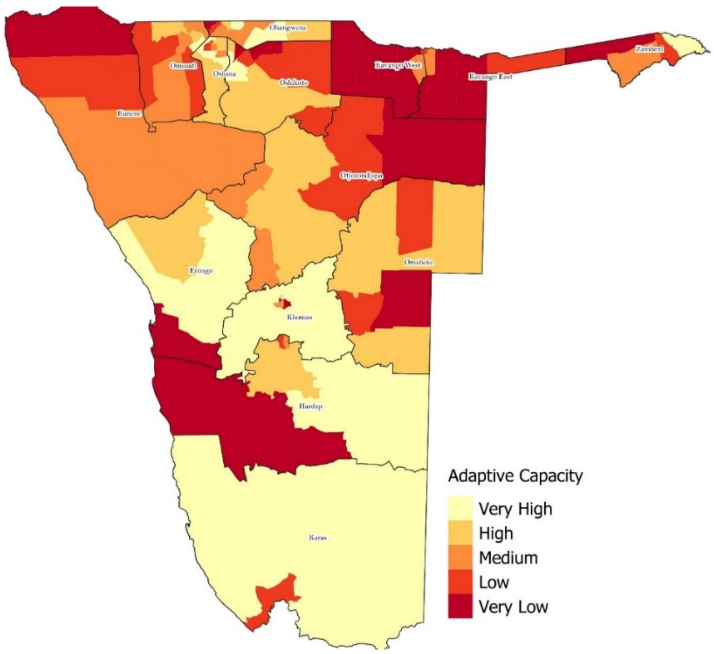


Figure 4.23 - Adaptive Capacity Map (degree to which constituencies can cope with climate change risks/threats)

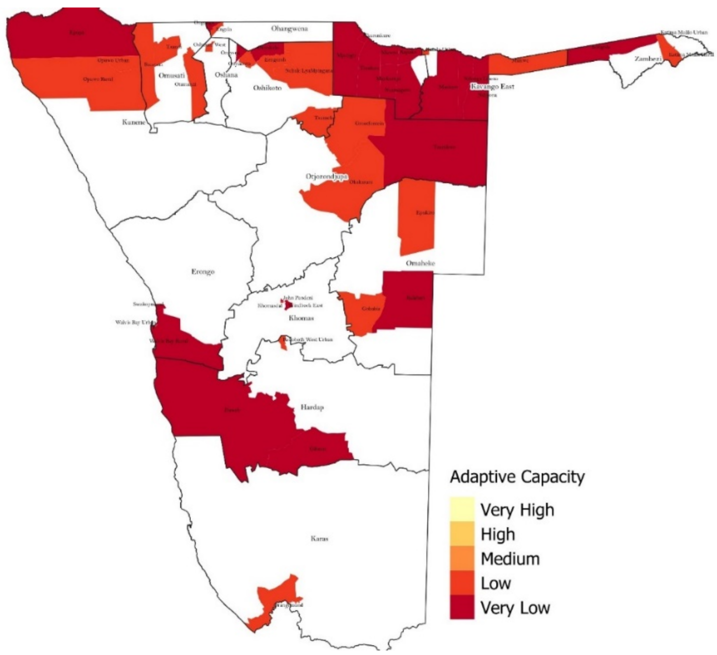


Figure 4.24 - Adaptive Capacity Hot Spot Map
(constituencies with low adaptive capacity to climate change risks/threats)

Adaptive capacity, whereas a smaller *adaptive capacity index* value indicates *low deprivation*, which means *high adaptive capacity*. The adaptive capacity of constituencies across Namibia is shown in Figure 4.23 and Figure 4.24. Figure 4.24 is a further refinement of Figure 4.23, and only shows the 'adaptive capacity hot spots', that is, constituencies with Low to Very Low *adaptive capacity*. The ranking of constituencies based on the *adaptive capacity index* is given in Appendix A.3.

The distribution of constituencies across the five quantiles of the computed adaptive capacity index is shown in Figure 4.25. Based on Figure 4.23, Figure 4.24 and Figure 4.25, a pattern of adaptive capacity of constituencies in Namibia is discernible. Generally, constituencies in the north-eastern parts of the country relatively have a low adaptive capacity, compared to other parts of the country. The mapping of all the constituencies, in Namibia, to the quantiles of the adaptive capacity index is given in Appendix B.3.

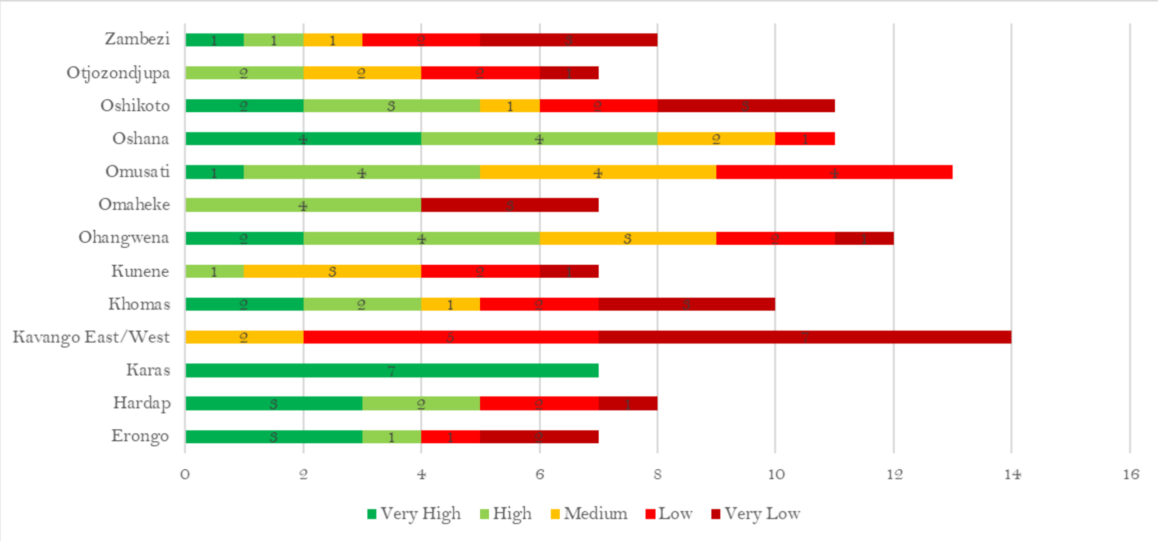


Figure 4.25 - Regional distribution of constituencies across the quantiles of the adaptive capacity index

Health, material, and service deprivation were found to be the key drivers of the adaptive capacity of constituencies in Namibia (Figure 4.26). These key drivers are critical for the design and implementation of climate change adaptation actions in Namibia. For instance, improving access to health services and information are critical to building the capacity of constituencies to deal with climate change impacts.

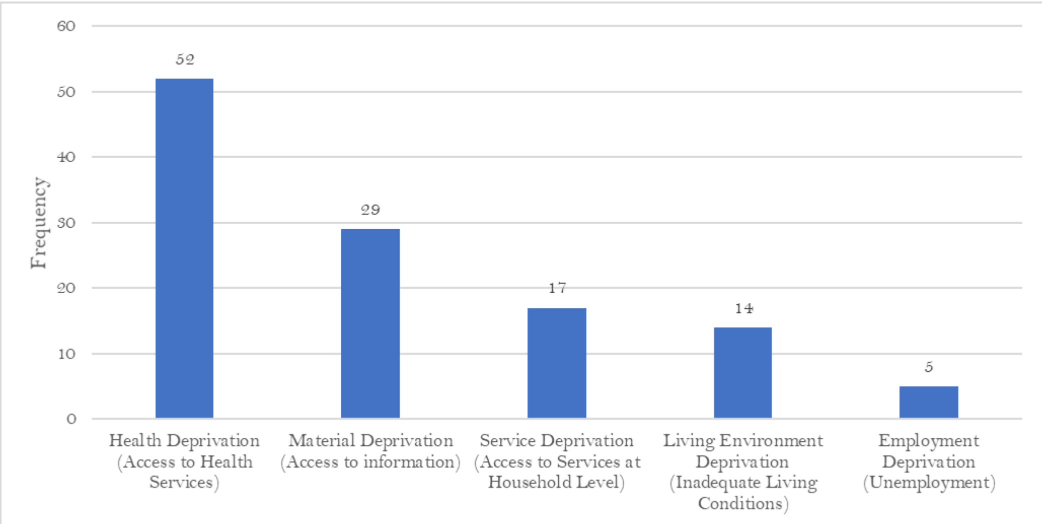


Figure 4.26 - The drivers of sensitivity to climate change risk in constituencies in Namibia

4.4.5. The Vulnerability of Constituencies

Under the IPCC framework, vulnerability is measured as a function of the exposure, sensitivity, and adaptive capacity attributes of a constituency. The vulnerability index (i.e., NCCVI) is computed using the PCA. The algorithm of the PCA procedure that was used to compute the NCCVI is presented in Appendix C of this report. The PCA algorithm computes the NCCVI as a weighted sum of the squared Principal Components extracted from the exposure, sensitivity and adaptive capacity variables. The NCCVI values, that is the weighted sum of the squared Principal Components, indicates the magnitude of climate change vulnerability of constituencies in relative terms. Larger NCCVI values indicate higher vulnerability, whereas smaller NCCVI values indicate low vulnerability.

The vulnerability of constituencies across Namibia is spatially presented in Figure 4.27 and Figure 4.28. Constituencies with a dark-red shading are more vulnerable to climate change impacts relative to those with a yellow shading (Figure 4.27). Figure 4.28, which is a refinement of Figure 4.27, shows the vulnerability of hot spots, constituencies that are relatively more vulnerable to climate change impacts. Appendix A.4 shows the ranking of all the constituencies in Namibia based on their NCCVI values.

The regional distribution of constituencies across the five quantiles of the NCCVI is presented in Figure 4.29. The NCCVI scores for most of the constituencies in the Omusati, Kavango (East and West) and Zambezi regions are high, implying that these constituencies are relatively highly vulnerable to the impacts of climate change. Most constituencies in the Karas, Hardap, and Erongo regions have low NCCVI scores, implying low vulnerability to climate change risk.

The number of climate change vulnerability risk hot spots (in terms of constituencies) across Namibia's 14 administrative regions is presented in Figure 4.28, Figure 4.29, and Figure 4.30. The Omusati region has the highest number of constituencies that are vulnerable to climate change impacts followed by the Kavango region (i.e., East and West). There are no hot spots in the Karas region. That is none of the constituencies in the Karas region had an NCCVI score within the High to Very High vulnerability category. The results presented in Figure 4.30 suggest a wide variation in constituency vulnerability across the country. However, the constituencies that are relatively more vulnerable to climate change are found in the northern parts of the country in the Omusati, Kavango East and West and the Zambezi regions. The mapping of all the constituencies of Namibia according to their degree of vulnerability to climate change risks/threats is given in Appendix B.4.

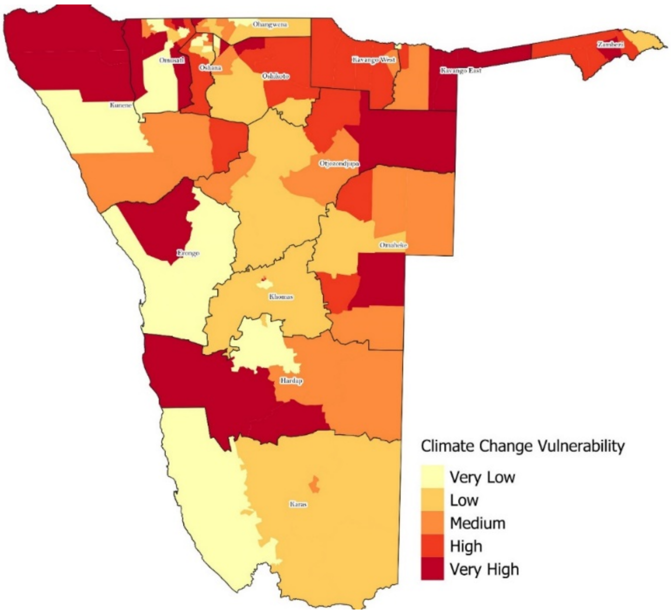


Figure 4.27 - The Vulnerability of Constituencies to Climate Change Impacts

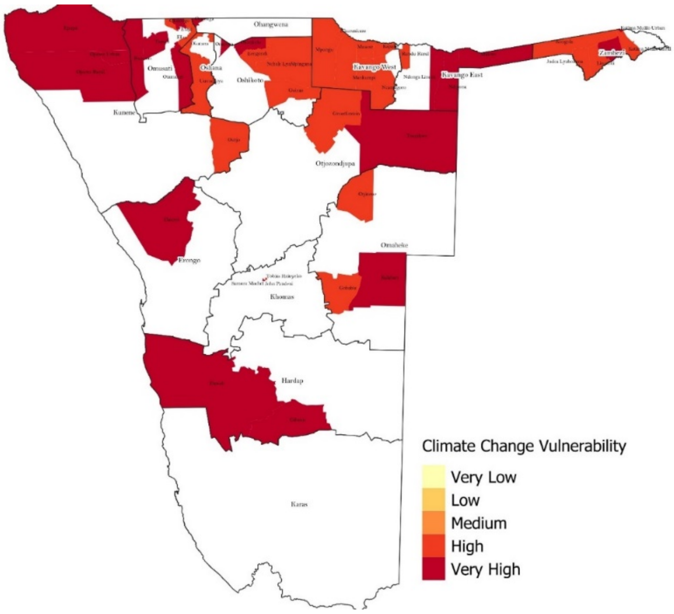


Figure 4.28 - The Vulnerability Hot Spots Map for Namibia

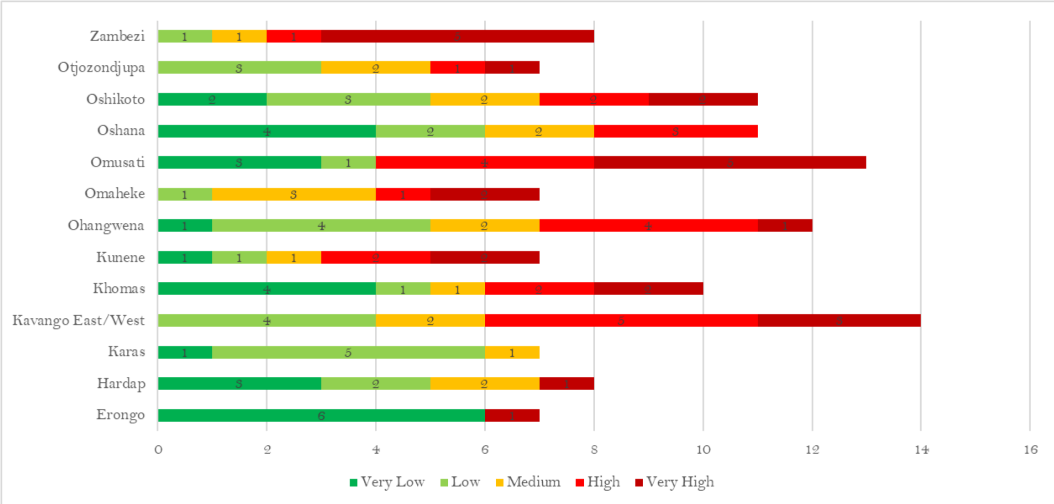


Figure 4.29 - The distribution of constituencies across the quantiles of the NCCVI

Climate change is considered as considered a key driver of rural-urban migration in Namibia. According to the NSA (2015), urban centres such as Windhoek, Oshakati, Swakopmund, and Walvis Bay are the key destinations for most migrants. Most of the migrants settle in informal settlements around urban centres, as evidenced by the increased sprawling of informal settlements around these areas. The influx of rural migrants into informal settlements has resulted in certain constituencies in urban areas to be highly vulnerable to climate change risks. Analysis of the result presented in Figure 4.29 as well as in Appendix B.4 shows that most of the vulnerability hot spots are urban constituencies.

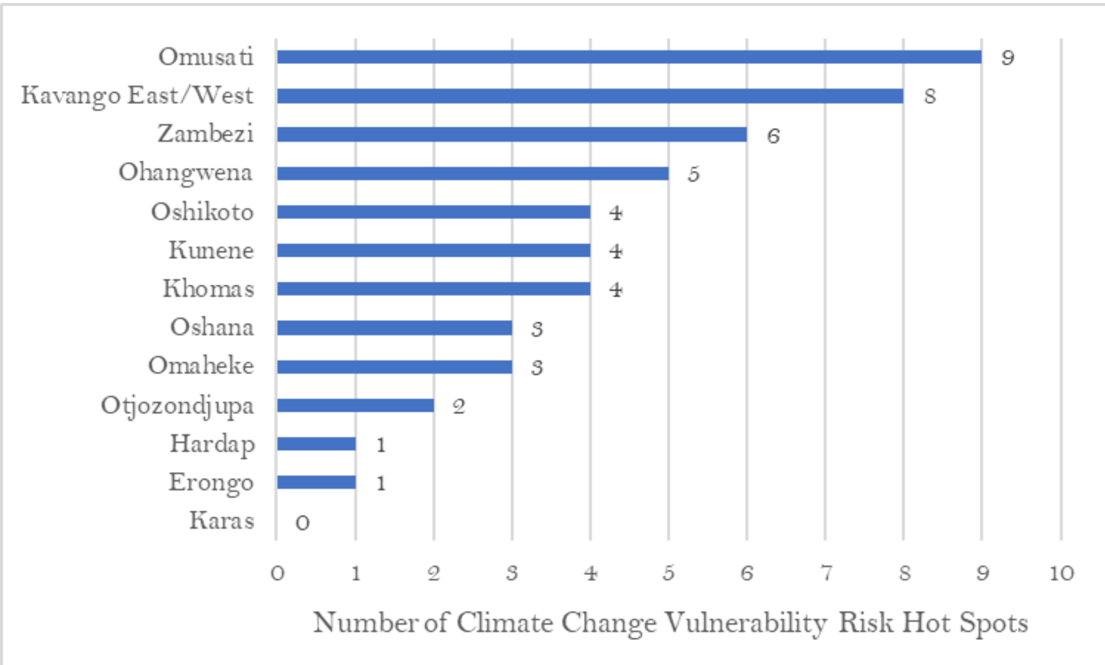


Figure 4.30 - The number of Climate Change Vulnerability Risk Hot Spots per Region

The increased vulnerability of urban constituencies to climate change risks and impacts can be attributed to what can be referred to as migration-linked vulnerability. As migrants move to urban centres, mostly informal settlements around major towns and cities, they bring along their sensitivities to climate change risks. As a result, the sensitivity to climate change risks in constituencies that host these migrants is also increased, thereby causing the constituency's vulnerability to increase. Migration-linked vulnerability in urban constituencies will certainly increase with the increase of rural-urban migration as well as urbanization. As a result, urban constituencies are in the long-run more likely to become more vulnerable to climate change risk compared to rural constituencies. Addressing migration-linked vulnerability will increasingly become an important area of climate change adaptation management

4.4.6. Key Findings

4.4.6.1. Vulnerability of Constituencies in Namibia

The study developed four indices using the IPCC definition of climate change vulnerability. The indices capture the climate, socio-economic, and political and institutional characteristics of constituencies across Namibia. The indices empirically measure the exposure (exposure index), sensitivity (sensitivity index), adaptive capacity (adaptive capacity index) and vulnerability (NCCVI) of constituencies to climate change. Based on the constructed indices, the study empirically estimated in relative terms, the degree to which each constituency in Namibia is exposed, sensitive able to cope and vulnerable to climate change risks. The relative degree of exposure, sensitivity, adaptive capacity and vulnerability of constituencies is spatially presented in maps in Section 4.4 of this chapter.

The results presented in Section 4.4 suggest a wide variation in the exposure, sensitivity, adaptive capacity, and vulnerability of constituencies to climate change risks/threats across the country. Generally, the north-western and north-eastern parts of the country host some of the most vulnerable constituencies, while the southern parts of the country (i.e., the Karas region) host some of the least vulnerable constituencies. The top three regions that host the most vulnerable constituencies are the Omusati, Kavango (East and West) and Zambezi regions. In these regions, and generally in all the vulnerable constituencies, high sensitivity (low resilience) and low adaptive capacity are the primary drivers of vulnerability to climate change. The study suggests addressing food insecurity, livelihood diversification and Multiple Deprivations (i.e., material, health and services deprivations) as key entry points for building resilience to climate change risks in the vulnerable constituencies.

The vulnerability map that has been created based on the NCCVI communicates the distributional impacts of climate change risks/threats on constituencies across Namibia. Constituencies that have high vulnerability are the ones that are likely to be hit hard by climate change linked hazards such as drought, high rainfall variability, floods, etc. On the other hand, the vulnerability map also shows constituencies that are resilient and can cope with or adapting to climate change threats. This classification of constituencies based on their vulnerability is important for planning adaptation actions and investments.

4.4.6.2. Migration-linked Vulnerability to Climate Change risk

A closer look at the vulnerability assessment results shows that migrant-hosting urban constituencies across Namibia have high vulnerability to climate change risks. The underlying driver of vulnerability in migrant-hosting constituencies can be attributed to the sensitivities to climate change risks that migrants bring along as they move to urban areas. Therefore, the increase in rural-urban migration will, in the long run, increase the sensitivities, and ultimately the vulnerability, of urban constituencies (i.e., specifically urban constituencies that host migrants) to climate change risks. Addressing migration-linked vulnerability is expected to increasingly become a key component of climate change adaptation management in Namibia.

4.4.6.3. Recommendations

(i). Climate Change Adaptation Planning

Identifying who or what is vulnerable to climate change and understanding the underlying drivers of this vulnerability is a critical step in climate change adaptation planning. Answers to these questions enable the design of tailor-made adaptation actions that effectively address climate change vulnerability as well as building climate change resilience. The 'vulnerability' and 'vulnerability Hot Spots' maps produced in this study have identified constituencies that are most vulnerable to climate change risks/threats as well as the underlying drivers of vulnerability in these constituencies. Therefore, these maps can be used as tools for planning climate change adaptation.

(ii). Prioritization of Adaptation Activities and Investments

One of the key outputs from the NC4-VA is the 'vulnerability' and 'vulnerability Hot Spots' maps. These two maps give a national overview of the distributional impacts of climate change risks/threats across constituencies in Namibia. Therefore, these two maps can be used as tools for prioritizing adaptation activities and investments. Constituencies with High to Very High NCCVI scores should be prioritized when planning adaptation activities and investments.

The use of the NCCVI to prioritize adaptation activities and investment study does not suggest a climate change adaptation strategy or policy that completely excludes the least vulnerable constituencies. Given the transitory and dynamic nature of climate change vulnerability, such a policy/strategy will make constituencies that are less vulnerable now, more vulnerable in the future.

Climate change risks should be viewed as a factor that depresses the resilience of a system. If this resilience is not enhanced, it will over time decrease, thereby increasing the susceptibility of the system to the risks/threats posed by climate change. Therefore, the study privileges an adaptation policy that is inclusive and targets all constituencies. The strategy within such a policy would be to urgently build resilience in the most vulnerable constituencies and enhance resilience in less vulnerable ones.

(iii). Evaluation of Climate Change Adaptation Programs

Presently, tools for independently tracking progress in terms of climate change adaption do not exist in Namibia. Therefore, the generated maps together with the developed NCCVI framework can be used as the basis for assessing the effectiveness of adaption actions as well as tracking adaption progress. For instance, the developed NCCVI framework could be implemented on a five-year cycle (consistent with the national development planning period) to update the vulnerability risk maps such as the those generated in this study. The generated vulnerability risk map can be compared to the previous cycle map to track the effectiveness of the climate change adaptation actions implemented during the five-year cycle.

(iv). Approaches to Climate Change Adaptation

The constructed NCCVI can be used to inform local-level adaptation actions and strategies that could effectively address the risks/threats posed by climate change to communities. It can also be used for awareness raising activities at the level of communities, policymakers and implementers at national, regional and constituency level, which will better prepare all stakeholders to manage climate change risks.

4.5 Climate change adaptation

The Vulnerability and Adaptation assessment should drive action plans within a well-defined framework. The latter should serve to implement and track actions for reporting to the UNFCCC. Successful implementation can only be possible when barriers and constraints are removed.

Namibia has created this framework within the National Climate Change Strategy and Action Plan (NCCSAP). Implementation of the NCCSAP is presented below with focus on ongoing and planned adaptation efforts emphasising on the key sectors agriculture, water resources, forestry, health, and tourism, existing barriers constraining adaptation , a new approach to address some of the chronic barriers, and key messages about climate change adaptation.

4.5.1. National Climate Change Strategy and Action Plan (NCCSAP)

To succeed, the NPCC will require institutional structures that are adequately equipped and can provide facilities and finances necessary to support climate change adaptation programs and activities. It is primarily for this reason that Namibia developed the NCCSAP to coordinate institutions and facilitate the mobilization of both private and public investments, foreign and domestic investments, to support the implementation of the NPCC. The NCCSAP for 2013 - 2020, which was approved by the cabinet in 2014, outlines strategic aims for adaptation, mitigation, and actions that cut across both topics, such as disaster risk reduction, capacity building, research, technology transfer, and training and institutional strengthening. Improving human and institutional capacity is described as a fundamental component of the overall strategy. With regards to adaptation, the NCCSAP outlines actions and implementation plans to meet vulnerabilities related to the following themes:

- Food security and sustainable resource base through agriculture, natural resources, marine and inland fisheries, and forestry.
- Sustainable water resource base through water availability and water demand management.
- Human health and well-being through control of climate-related and vector-borne diseases.; and
- Climate proofing infrastructure through standards, designs, regulations and integrated town and regional planning.

Each theme of the NCCSAP has strategic aims that have specific actions, targets, time frames, a designated lead agency, and budget allocations to build Namibia's adaptive capacities. The monitoring and evaluation framework of the NCCSAP requires the lead agency, together with other relevant stakeholders, to report on progress made with regards to the implementation of their designated actions.

A summary of the progress made with regards to the strategic aims of the NCCSAP are presented in Table 4.4.

Table 4.4 - Status of implementation of NCCSAP Adaptation actions

Food security and sustainable resource base	
Strategic Aim	**Progress**
• Climate change understanding and related policy responses in food security are further improved.	• National and sub-National Food and Security and Vulnerability Assessments and SADC Regional Vulnerability and Assessment Analysis (RVAA) were implemented
• Develop, identify and disseminate climate resilient crop farming practices.	• Disseminated through the Conservation Agriculture Programme and previous and existing projects CCP NAM, AAP, SCORE, NAFOLA, CRAVE, and EMPOWER TO ADAPT. Dissemination is ongoing through the Ministry of Agriculture, Water and Forestry (MAWF), National Farmers Union, Namibia Agricultural Union and the Agronomic Board.
• Identify (pilot) climate-resilient livestock breeds with local farmers and herders.	• Piloting has been done in many areas and ongoing. Based on successes, mainstream such breeds into traditional meat value chains.
• Further, promote game meat as a sustainable animal protein source for domestic food supply.	• Initiated and to be strengthened into traditional meat-value chains
• Best sustainable land management (SLM) and suitable land-use practices are tested and implemented at both national and local levels.	• The third National Action Programme for Namibia to implement the United Nations Convention to Combat Desertification (UNCCD) was developed in 2015, and a National Steering Committee established to test SLM efforts at five hotspot areas. To be strengthened and case studies developed for the Namibia Desert Ecosystem zone to be replicated country-wide
• Early Warning System (EWS) and Climate Risk Management (CRM) systems are developed/improved and implemented.	• To be implemented under the National Disaster Risk Management Plan enabled by the National Disaster Risk Management Act and Policy.
• Adaptation strategies are improved by monitoring and establishment of baseline data on extreme events.	• Baseline data established through a centralized knowledge management system coordinated by NSA and the adoption of a core set of United Nations Framework for the Development of Environment Statistics (UNFDES). This will entail the review of the current Core Environmental Indicators in the Integrated State of Environment Reporting (ISoER).
• Conservation measures to utilize sustainable forest resources for food security are in place and implemented at the community level, building climate change resilience.	• To be strengthened by the operationalization of community-based forest management approaches in gazetted community forests.

• Encourage approaches that lead to sustainable management and utilization of fisheries and marine resources.	• Benguela Current Convention ratified by the Governments of Angola, Namibia, and South Africa for the legal establishment of the Benguela Current Commission (BCC). The GEF is currently funding two projects to improve climate change adaptation and resilience capacities, one project to implement the Convention and the Strategic Action Plan of the BCC and, another to improve climate-adaptive capacities in the fisheries sector. Draft joint management plans in place for Cape hakes and Cape horse mackerel, the two commercially important shared fish stocks. Namibia Marine Resources Act revised to improve on the input controls to reduce overfishing and unselective fishing and ecosystem destruction.
• Promote integrated fisheries and marine resources management.	• Namibia Marine Resources Act revised in 2015 to improve the process of fishing rights allocation and input controls. The BCC promotes an ecosystem-based approach to the management of the large marine ecosystem as an adaptive and resilience capacity-building approach.
• Strengthen and encourage integrated coastal zone management plans for the protection of marine life.	• Namibian Policy on Coastal Management (NPCM) endorsed in 2012 and Integrated Coastal Zone Management Bill in place.
• Conservation, utilization and development of biological resources and maintenance of resilient ecosystems to ensure climate resilience and environmental sustainability.	• The BCC's Strategic Action Programme addresses climate change thorough and the GEF/FAO Project on Climate Change Adaptation in Fisheries serves to improve resilience and livelihood sustainability of communities.

Sustainable water resources base

Strategic Aim	Progress
• Further improve the overall climate change understanding and related policy responses in the water resources sector.	• To be strengthened by enactment of regulations supporting the Water Resources Management Act.
• Monitoring and data collecting technologies of surface and underground water are developed and implemented at the basin/watershed level.	• To be strengthened through Integrated Water Resource Management (IWRM) and basin management platforms.
• Strategies for harvesting and capturing water during rainy season are well formulated and implemented, and guidelines for more efficient water use by sectors, households and individuals are provided.	• Best practices and lessons from the GiZ community-based interventions and Gobabeb Training and Resource Centre (GTRC) to be replicated and upscaled countrywide at different scales as viable. Neckartal Dam completed and development of the Ohangwena II aquifer and Calueque Dam in southern Angola to be continued
• Improve access to sanitation and safe drinking water for all, particularly in flood-prone areas.	• NDP 5 aims to improve sanitation at household level by 2022/23; from 28% to 40% in rural areas and from 77% to 87% in urban areas. At present, 72% of rural households engage in open defecation.
• Promote conservation and sustainable utilization of water resources.	• MAWF's Comprehensive Conservation Agriculture Strategy promotes water-efficient agriculture while at community level micro-drip irrigation is a growing practice that has been further mainstreamed by projects such as NAFOLA and the GEF/UNDP Small Grants Programme. Current and emerging initiatives such as the EIF's GCF-funded adaptation and NILALEG serve for further mainstreaming of micro-drip irrigation for food production.
• Improve trans-boundary cooperation regarding water resources.	• Namibia is a party to sustainable management and improved conservation of transboundary water resources through different kinds of agreements. These include the transboundary perennial water basins of Kunene, Okavango, Kwando, Zambezi and Orange Rivers.
• Support institutional and human capacity building in integrated water resources management and use.	• In progress at national, regional and local (community-based) levels. Rainwater harvesting, storage, and access is an IWRM approach at the community-based level while purification and reuse of wastewater could be improved as an IWRM approach at the regional level. Desalination of seawater powered by renewable energy is globally recognized as an IWRM approach for coastal countries, and Namibia can still harness this potential to improve water security. A seawater desalination pilot study was launched in March 2019, using a containerized desalination solution that delivers 3,500 liters of water per hour and has 70% less operating costs due to renewable energy. The systems also purify water from chemicals, bacteria, and viruses. With the support of the Adaptation Fund, pilots are underway in southern Namibia desalinate brackish freshwater using renewable energy. These two pilots could offer viable long-term

	solutions given Namibia's access to the sea and, the vast amount of underground saline water.

Human health and wellbeing

Strategic Aim	Progress
• Strengthen disease prevention and treatment for those diseases expected to increase due to climate change.	• They are strengthened through the Global Fund investments in the reduction of malaria, tuberculosis, cholera, and hepatitis. Since 2018, when a hepatitis E outbreak was declared, some 4,500 cases were reported including 34 deaths of which 16 were maternal. Sanitation is poor in informal settlement and rural areas and contaminates water that is consumed by people. Areas can be disinfected using effective microorganisms as a human and environmentally friendly substance.
• Develop adaptation mechanisms to climate change-related health risks and disseminate information for effective preparedness.	• It is developed through Global Fund initiatives.
• Strengthen the existing mechanisms for the vulnerable groups to access basic services and health facilities during climate-related emergencies.	• They are developed through the National Disaster Risk Management Policy and Strategies under the auspices of the Directorate of Disaster Risk Management.
• Establish, improve, and enforce standards for infrastructure development and develop infrastructure that is more resilient to climate events, and integrate climate change issues into design and development planning strategies.	• No standards are in place since the 2015 3rd National Communication. In 2018 Namibia developed Hospital Standards and Criteria (HSC). This does not include climate change resilience and adaptation, particularly as far as health facilities are affected by periodic floods. There is a need to address health infrastructure resilience, and the HSC can incorporate these as an additional chapter.
• Encourage the adoption of town and regional planning and development standards and principles toward climate-resilient human settlements.	• The NC3 made recommendations for improving the resilience of the town of Oshakati. See the above section about water-related adaptations in northern Namibia. • To be developed through the ministry responsible for urban and town planning, the Namibian Standards Institution (NSI) and its appropriate technical committee, and the Green Building Council of Namibia.
• Encourage adjustment of designs and environmentally sensitive construction and maintenance methods.	• Review of the building codes and associated guiding frameworks were proposed for coastal areas given the results of modeled inundation due to sea-level rise. Recommendation of seawalls and other measures were proposed since the NC2, and some have been constructed as part of waterfront developments. • To be developed through the ministry responsible with urban and town planning, the Namibian Standards Institution (NSI) and its appropriate technical committee, and the Green Building Council of Namibia

Climate proofing infrastructure

Strategic Aim	Progress
• Establish, improve, and enforce standards for infrastructure development and develop infrastructure that is more resilient to climate events.	• No climate resilient-specific standards for infrastructure in place while there are recommendations to improve resilience in flood-prone and coastal areas.
• Encourage the adoption of town and Local Authorities, the Association of Local Authorities and regional planning and development standards and principles toward climate-resilient human settlement.	• Namibia has a Green Building Council with standards associated with climate change resilience. For the town of Oshakati, central-north Namibia, there is an infrastructure improvement recommendation to divert period floodwaters away from people and infrastructure to limit the impact and damage of flooding. This has not been implemented yet. Seawalls have been constructed for new coastal developments to provide some buffering. It is not known whether such developments incorporated sea-level rise modeling to influence the specifications of seawall design and construction.
• Encourage adjustment of designs, and environmentally sensitive construction and maintenance methods – integrating climate change issues MET, MAWF into design and development planning strategies.	• Private buildings and infrastructure have adopted climate-buffering and mitigation approaches. Several commercial buildings are powered using renewable energy while some are designed and built using "greening" standards. These include the Old Mutual Insurance and Investment and; the Rand Merchant Bank/ First National Bank headquarters in Windhoek. These buildings have received ratings from the Green Building Council.

4.5.2. Climate Change Adaptation Actions in Namibia

Namibia is highly vulnerable to the impacts of climate change due to its geographic location, its climate variability, and various socioeconomic factors such as poverty, inequality, and unemployment among others. Strategic adaptation measures, particularly in the vulnerable and economically important sectors such as agriculture, tourism, and fisheries, are required to help Namibia adapt to climate change. To provide a picture of the degree to which these required investments are being made today, this section gives an overview of current adaptation priorities, adaptation status, and the alignment of current adaptation activities with the strategic themes/areas of the NCCSAP. The section concludes an analysis of the domestic adaptation investments (mainly public sector) and the scale of adaptation investments flowing into the country.

4.5.2.1. Current Adaptation Priorities

Namibia's current adaptation are identified in the NPCC and NCCSAP. These priorities are aligned with those sectors identified as being particularly vulnerable to climate change: water resources and wetlands; agriculture; sea-level rise, the coastal zone, and fisheries; tourism; health; and disaster risk management (Table 4.6).

Table 4.5 - A review of the Integration of climate change into national policies, sectoral strategies and development plans

Sector	National Policies/Development Plans/Strategies	Level at which climate change is mainstreamed into the policy/strategy/instrument			
		Absent	Climate Change identified as a potential risk	Possible actions for reducing risk identified	Targets for specific adaptation measures identified
Agriculture	National Agricultural Policy (2015)		✓		
	Dry Land Crop Production Programme (DCPP)		✓	✓	
	Green Scheme Policy (2008)	✓			
	National Forestry Policy		✓	✓	
Water	National Water Policy White Paper (2000)	✓			
	Integrated Water Resources Management Plan (2010)		✓	✓	✓
	Water Supply and Sanitation Policy (2008)	✓			
Health	National Health Policy Framework (2015)		✓		
	National Malaria Policy (2005)	✓			
Cross-cutting	National Gender Policy (2010-2020)		✓		
	National Policy for Disaster Risk Management		✓		
	National Disaster Risk Management Plan		✓		
	Harambee Prosperity Plan (2016-2020)		✓		
	Fifth National Development Plan (2017-2022)		✓	✓	✓
	Revised National Land Resettlement Policy (2018-2027)	✓			

Table 4.6 - Current Adaptation Priorities in Namibia

Sector	Current Adaptation priorities
Agriculture	▪ Diversify crops to hedge against erratic rainfall and shorter seasons ▪ Increase the use of improved crop varieties ▪ Prioritize seawater desalination ▪ Protect all surface water and groundwater resources from pollution by regulating discharges ▪ Use livestock management strategies, including fall-back grazing areas and mixing small and large stock herds of various breeds ▪ Use crop modeling to inform decision-making ▪ Implement crop germplasm conservation/evaluation and breeding

Sector	Current Adaptation priorities
	▪ Improve and conserve indigenous livestock breeds Increase seed and fertilizer availability ▪ Increase use of protected cultivation and livestock systems (e.g., greenhouses, net houses) ▪ Improve shared water resource management ▪ Introduce drought mitigation measures ▪ Use water only for irrigation of high-value crops
Water Resources	▪ Provide full support for integrated water resources management ▪ Focus on reducing evaporation and improving the efficiency of water use ▪ Coordinate use of surface and groundwater resources and artificially increase the recharge rate of groundwater aquifers to reduce evaporation ▪ Improve water demand management, particularly at the local level, and in the agricultural, industrial, mining, and tourism sectors; expand stakeholder engagement ▪ Monitor and control groundwater use more strictly
Coastal zone and Marine Fisheries	▪ Create effective communication campaigns ▪ Introduce legislation to reduce property and infrastructure development in environmentally sensitive areas and areas at risk of sea-level rise ▪ Research and monitor sea-level rise ▪ Undertake vulnerability mapping ▪ Collaborate with the insurance market to guide investment in coastal areas ▪ Develop an early warning system ▪ Rehabilitate wetlands and estuaries ▪ Replenish beaches and dunes ▪ Raise infrastructure to protect ports and certain roads ▪ Install sea walls, barriers, and barrages
Tourism	▪ Promote sustainable tourism ▪ Implement conservancies, tourism, and adaptation programs based on community-based natural resource management ▪ Promote community-based natural resource management data collection and archiving ▪ Improve water management ▪ Diversify livelihoods
Health	▪ Strengthen the capacity of health professionals in epidemic preparedness and response ▪ Recruit and train community health workers to provide emergency first aid ▪ Improve staff training on the prevention and treatment of malnutrition ▪ Enhance and further mainstream climate-related awareness ▪ Improve access to timely and relevant information ▪ Undertake scenario development and proactive planning to address both fast-onset and slow-onset climate-induced events ▪ Strengthen the policies required to address both slow-onset and catastrophic events effectively ▪ Develop health-centre adaptation strategies ▪ Climate-proof the public health system ▪ Strengthen water and sanitation systems
Disaster risk management	▪ Strengthen capacities for disaster risk preparedness, contingency planning, and risk reduction ▪ Implement vulnerability and risk mapping ▪ Improve information flow and communications between formal structures at the national, regional, and community levels ▪ Support community-based adaptation practices ▪ Improve monitoring and documentation of extreme events ▪ Develop pro-poor disaster insurance schemes

Source: Crawford and Tretorn, 2016) Adaptation Status Quo

This section provides information on current climate change adaptation programs and projects that are being implemented in Namibia. These programs and projects were identified through an extensive review of online resources and websites of UN agencies, multilateral development banks, bilateral development agencies, and international and national NGOs. The review of the programs and projects was based on the following parameters:

- The review defined an adaptation program/project as one that is designed and implemented specifically to address the current and projected impacts of climate change. Therefore, the words or phrases "adaptation," "climate change adaptation (CCA)," "climate risk management," and "climate vulnerability reduction" were the key terms that were used as markers for searching and identifying the projects and programs.
- The cut-off period for the review process was the year 2014 when the preparation of the Third National Communication had advanced. This was done to ensure that the projects and programs reported on ere those were being implemented during the period 2014-2019. It is highly likely that information on these projects and programs was not captured in the Third National Communication (NC3).

Based on the above parameters, a total of 32 programmes and projects were identified. Most of the current climate change adaptation projects, and programs in Namibia are directed in the areas of agriculture, fisheries, sustainable land management, government, climate information and research, ecosystems and biodiversity, forestry and energy. The projects tend to focus on capacity building, knowledge communication, field implementation, and policy formation and integration, with all nationally implemented projects supporting community-based adaptation.

Regions within Namibia that are particularly targeted for adaptation interventions are the northern parts of the country, including Kavango, Zambezi, Oshikoto, Oshana, Ohangwena, Omusati, and the northern part of Kunene Region. Regions in the Southern part of the country seem to be less targeted by adaptation projects and programs. This could be primarily due the high vulnerability and population density in the northern part of the country as opposed to the lower vulnerability and population density in the southern parts of the country.

Most of the adaptation activities are implemented with funding donor and international multilateral institutions such as the Green Climate Fund, Adaptation Fund, Global Environmental Fund (GEF), European Union (EU), United States Agency for International Development (USAID), GIZ, Japan International Cooperation Agency (JICA), etc. However, local institutions such as the Environmental Investment Fund also provide support to climate change adaptation activities.

4.5.2.2. Sectoral Adaptation Overview

Climate change adaptation in Namibia has focused on improving the resilience and adaptive capacities of sectors and the associated functions, infrastructure, and human resources (MET 2002, 2011, 2015). Since 2013, the NCCSAP articulates the climate change adaptation priorities for Namibia (Table 4.6). Much of these priorities have been or are being delivered through a blend of public and private finance, including publicly financed cross-sector rural development, and small-, medium and full-sized[4] donor co-financed[5] projects. These interventions aimed at improving adaptive and resilience capacities among government technical and extension staff, rural communities and nature-/ community-based enterprises,

[4] According to the Global Environment Facility (GEF) and, during the early to mid-2000s, full-sized projects had average budget sizes of U$5 million over 3-5 years;

[5] Multilateral and bilateral investments are made on the premise that the government pledges co-finance in cash and in-kind.

strengthening the institutional and policy frameworks, raising awareness and understanding of climate change and, enabling the transfer of technologies. The following section highlights some of the key sectoral adaptation in Namibia.

Agriculture sector

In the agricultural sector, adaptation measures have, and still include conservation agriculture and tillage, switching to more climate-resilient species and livestock breeds, converting encroacher bush to animal feed and other products, while other measures include conversion of land use from livestock farming to animal wildlife management and tourism. The UNDP/GEF Small Grants Programme, since 2002, and the Environmental Investment Fund of Namibia since 2014 as the dedicated community-based investment mechanisms, have significant geographic footprints of agricultural community-based adaptation (CBA) activities, particularly those that involve women, youth and children. Soil fertility and the use of appropriate fertilizers are high priorities for MAWF and its stakeholders to improve soil productivity in Namibia. Building on current efforts, ongoing adaptation measures should scale up the use of balanced organic fertilizers (kraal manure), explore the application of mulch derived from encroacher bush biomass, minimize evaporative water loss and, enable the mulch to decompose over time and fertilize the soils.

De-bushing (i.e., the thinning of encroacher and invasive species) and the integration of bush-to-feed into the livestock production systems have become prime priorities in the Namibian agriculture sector. Since 2016, over 6,200 commercial and communal farmers have adopted bush-to-feed conversion as an adaptation measure. Increasing accessibility of information and technical support, suitable and affordable bush value chain technology through local manufacturing have led to widespread adoption of this adaptation measure by farmers. Reports of animal weight gains and feeding rations, recorded during feeding trials carried out by development partners, provide proof to farmers that this adaptation measure works and delivers the co-benefits of rehabilitating rangelands and, lowering operational costs due to lower cost of this bush feed. Bush helps to secure fodder flow systems throughout the year and raises farmer's adaptive capacity to seasonal livestock feed supply fluctuations. Animals need adequate nutrition every day. So fodder banks are critical to adapt to intermittent shortages and should be rolled out.

Water sector

The water sector has prioritized five large-scale adaptation measures which include conjunctive use of surface and groundwater resources; improving water demand management; controlling the use of groundwater; improving the policy and legal framework for water management, and expanding stakeholder engagement (MET 2015). The conjunctive use of surface and groundwater resources serves as an adaptive approach to mitigate water loss through evaporation. This is a well-established and working strategy that entails pumping water surface water into aquifers for underground storage, thus avoiding evaporation loss.

As part of an adaptive response to flooding events of 2008, 2009 and 2011 in the north-central areas, to buffer people, their assets and infrastructure, a Master Plan is in place for flood mitigation with a budget of US$105 million. This includes a series of earth dykes planned for around Oshakati town to keep the floodwater of the 'Efundja' at bay. The town and immediate surroundings are within a natural floodplain and, once the town is inundated, it is extremely difficult to remove flood waters due to no lower-lying areas for the diversion of water. Particularly vulnerable are the wastewater treatment ponds that overflow during flood events, causing breaches of the earth walls and spillage of sewage water into the flooded areas. This leads to human and environmental health impacts – such as contamination of water and outbreaks of water-borne disease that exacerbates people's suffering during times of flooding.

The Master Plan, designed to have long-term positive impact, includes a dyke around the northern and western sections of Oshakati, diverting water to the south; deepening of the Okatana River in Oshakati and lining of its banks with concrete (Enviro Dynamics 2012). However, the implementation of the Master Plan, including the construction of additional dykes, is on hold due to budgetary constraints related to Namibia's prevailing economic depression that has led to fiscal consolidation (BoN, 2018).

Rainwater harvesting and reuse have been piloted successfully in north-central Namibia and elsewhere and show potential to improve livelihood and food security and raise resilience (GiZ 2015). Due to a historic threat that malaria may spread to central and southern Namibia, particularly due to exposed surface water becoming mosquito breeding grounds (ref, City of Windhoek), no legislation exists that neither prohibits nor permits this practice. Namibia has nearly eliminated malaria due to increased access to insecticide-treated nets (ITNs) and, modeling suggests no threat due to a drier climate that is predicted for the future (Willemse, 2018). Hence, a conducive policy environment that enables the rolling out of successful rainwater harvesting and safe collection approaches can significantly improve water and food security at the local level.

Forestry

Adaptation in the forestry sector has been promoted through the establishment and expansion of forest reserves (state, regional and community forest reserves) and forest conservation and sustainable management (SFM). At present Namibia's woodland forests (areas with trees >5 m height) cover about 25% of total land surface area, at some 7 million ha. Registered Community Forests presently total 35, of which 21 are gazetted and 14 emerging. Savannahs cover the largest land surface area at 54.5% representing areas with three <5 m height. In 2012, MAWF instituted a moratorium on the issuance and harvesting of timber, due to a spate of illegal timber harvesting. By 2013, MAWF considered lifting the moratorium due to public pressure for permits to harvest and sell timber.

The Ministry acknowledged a sub-optimal system for the monitoring, verification, and reporting of legally harvested timber which was further exacerbated by timber coming from Angola and Zambia. The current system does not record the origin of timber and thus cannot differentiate between timber from Namibia, compared to legally or illegally imported timber from the mentioned countries.

Due to the ongoing deforestation, the World Economic Forum downgraded Namibia's Travel and Tourism Competitiveness rating in their 2017 report. The competitiveness rating considers the status of natural resources (incl. forests), business environment, air transportation, and price competitiveness. Due to the inclusion of deforestation, Namibia's ranking dropped by 12 points, affecting tourism which is the second most important contributor to the national economy, currently the only growing sector amidst a deep economic recession since 2014/15 and important for job creation. Hence, the destruction of woodlands leads to overall economic losses that translate to lower and loss of household and individual incomes, increase livelihood and food insecurity and destruction of biodiversity. The Ministry of Environment and Tourism estimated that more than 60,000 mature woodland trees had been harvested to date.

Health

In the health sector, major improvements were in the areas of disaster and risk reduction preparedness and response, proactive management in forced migration situations, improved responses to cholera outbreaks and control of malaria, and commitments to improving nutrition by addressing food security with MAWF and other partners (MET 2015). Disease surveillance improved while there is a need to improve data gathering and reporting. Following the 2009 floods, a designated Cholera Outbreak Response Team has been put in place, complemented with Cholera Treatment Centres (CTCs), the provision of safe water, proper sanitation and health education. Cholera can be prevented through improved hygiene and the safeguard of people and resources from raw sewerage. However, once an outbreak is detected, the time of reporting is critical to activate a response to ensure containment and treatment. Areas prone to cholera and hepatitis outbreaks can be treated with effective microorganisms to decontaminate areas and render them hazard-free for prolonged periods. Such inexpensive, easily accessible, human and environmentally friendly substances should be explored, in concert with other strategies to improve sanitation and hygiene, to prevent outbreaks. A National Malaria Strategic Plan 2010-2016 is in place to eradicate indigenous transmission of the disease by 2020. Namibia has achieved near-universal eradication by improving and enabling access to mosquito nets. The Strategic Plan is implemented through the National Vector-born Disease Control Program (NVDCP) and aims to improve early detection and response. The health systems climate change preparedness and response could be aided significantly by implementing the recommendations from the 2009 Post Disaster Needs Assessment, which included:

- Undertaking scenario development and pro-active planning to address both fast-onset and slow-onset climate-induced events.
- Strengthening the policies required to address both slow-onset and catastrophic events effectively.
- Improved data collection and surveillance to prepare for climate-induced changes.
- 'Climate-proofing' the public health system to deal with adverse health repercussions and outcomes from climate-related changes; and
- Ensuring that water and sanitation systems are strengthened.

Tourism

Adaptation in the tourism sector relies to a great degree on the success of adaptation and resilience capacity development in previously mentioned sectors, that is, agriculture, forest, water, and health sectors. The quality of, and access to water and the status of biodiversity, ecosystems, and landscapes, which are in many ways impacted by the agriculture sector also indirectly affect the adaptive capacity of the tourism sector. Furthermore, the tourism sector is also affected by the health sector and, specifically malaria outbreaks as well as flood-induced cholera and hepatitis. Therefore, on-going and proposed adaptation interventions in the other sectors will also have a positive impact on the tourism sector. However, there are specific adaptation actions that are required for the tourism sector in Namibia. These actions are highlighted in the NCCSAP.

4.5.2.3. Alignment of Current Adaptation Activities with NCCSAP

The current adaptation projects and programs were analysed further to assess their coverage in terms of the Adaptation Agenda of the NCCSAP (i.e., Agenda A, which focuses on climate change adaptation strategic themes and aims). Agenda A of the NCCSAP has four themes:

- A1 – Food Security and Sustainable Resource Base;
- A2 – Sustainable Water Resources Base;
- A3 – Human Health; and
- A4 – Infrastructure.

Out of the 32 identified projects and programs, 22 programs and projects primary focussed on climate change adaptation while the others had either a research focus or were multi-sectoral/cross-cutting. Of the 22 programs and projects, 20 were aligned to Theme A1, while the remaining two were aligned to Theme A2. None of the projects and programs directly addressed climate change adaptation issues in Themes A3 and A4. Therefore, human health (Theme A3) and infrastructure (Theme A4) are not receiving targeted attention in current programming.

4.5.3. Namibia's Adaptation Financing Landscape

The NCCSAP recognizes the need for intensifying the mobilization of domestic and international investments to support its implementation. The NCCSAP acknowledges the crucial role that international climate finance will play in Namibia's climate change adaptation and mitigation (Republic of Namibia, 2013). Based on current adaptation programs and projects, since 2014 Namibia is expected to have invested over US$175 million in adaptation. These investments are mainly from multilateral climate funds and bilateral donor organizations. However, the Namibian Government also supports, through the National Development Budget, climate change adaptation programs.

4.5.3.1. Public Sector Adaptation Investments

Information and data on climate change adaptation investments from both the private and public sector in Namibia is not readily available. Given the increasing recognition, in Namibia's sectoral and national development plans, of potential risks and threats of climate change, tracking domestic investments in climate change adaptation is crucial. The tracking of domestic investments in adaptation activities could be achieved in two ways. First, increase the participation of the private sector in the implementation of the NCCSAP. By so doing, the private sector will have a platform for reporting climate change adaptation activities and investments they have done. Second, public sector investments can be tracked by developing markers to identify programs and projects that support climate change adaptation in Namibia. The starting point and key resource for tracking public sector investments are the National Development Budgets compiled by the National Planning Commission.

To estimate the level of public sector investments into climate change adaptation, an analysis of the National Development Budget for the period 2014-2018 was done. The purpose of the analysis was to identify climate change adaptation programs and projects that the Namibian Government is funding. The National Development Budgets for the period mentioned above were reviewed using "adaptation," "climate change adaptation (CCA)," "climate risk management," "climate vulnerability reduction," and "drought risk reduction" as keywords. Through this review, a total of 22 government programs and projects were identified as climate change adaptation interventions. The amount of investment that government has committed to these projects and program for period 2014-2018 are presented in **Error! Reference source not found.**. The trend shows that public sector investments into adaptation is on the decline.

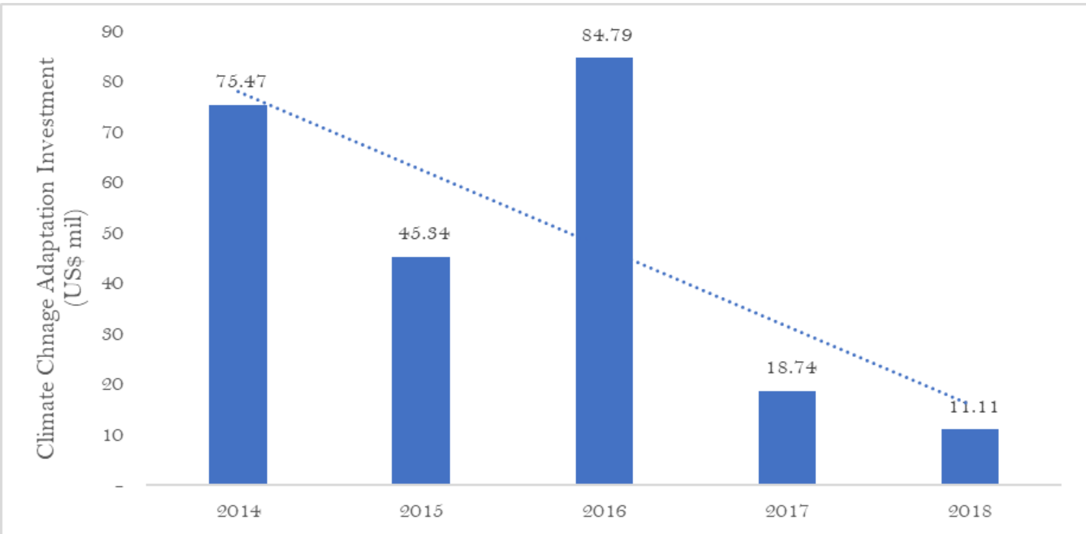


Figure 4.311 - Estimate of Public Sector Investments in Climate Change Adaptation Activities (2014 - 2018)
Note: based on 2018 exchange rate

4.5.3.2. Multilateral Donors

In the multilateral donors' space, the Global Environment Facility (GEF) through its implementing entity UNDP, has been the biggest and consistent funder, implementor and supporter of climate change adaptation and mitigation actions in Namibia. To date, GEF has supported a total of 66 projects, consisting of national, regional and global projects. The total funding the GEF has provided to Namibia to date, that is, in the climate, environment and energy sectors – is estimated at US$345.68 million in grants and

US$ 2 213.49 million in additional co-financing[6]. The programming and implementation of GEF 6 commenced after Namibia's NC3 to the UNFCCC. Namibia's GEF 6 is about US$14.2 million, of which about US$10 million has been committed to the focal areas of climate change (22%), biodiversity conservation and management (38%), and land degradation (40%).

Furthermore, Namibia's GEF 6 programming is based on an integrated landscape management approach. The focus areas of GEF 6 – climate change, biodiversity conservation and management, and land degradation – are and will be implemented using synergetic approach. This would ensure that biodiversity and land degradation actions would also contribute to climate change adaptation and resilience capacity building, and to the use of climate change data to inform biodiversity and land degradation interventions.

The Green Climate Fund (GCF) and Adaptation Fund (AF) are the new entrants in Namibia's climate financing landscape. These multilateral donors became active in Namibia after the NC3. To date, two national institutions in Namibia have been accredited to the GCF and the AF. The national institutions that have been accredited are the Environment Investment Fund to the GCF, and the Desert Research Foundation of Namibia (DRFN), to the AF. The accreditation of a third national institution, the Development Bank of Namibia is underway.

The accredited institutions are tasked with the mandate of mobilizing financial resources from the GCF and AF for the implementation of the climate change mitigation and adaptation actions, ideally in line with the NPCC and the NCCSAP. Thus far, the EIF has managed to mobilize more than US$30 million for the implementation of several climate change adaptation projects in Namibia. Furthermore, the DRFN has managed to mobilise about US$ 5 million for the piloting of an adaptation project in the water resources management theme of the NCCSAP. The description of the climate change adaptation and mitigation projects funded by the GCF and AF are highlighted in Appendix D. Details on these activities are available on the EIF and DRFN websites, respectively.

4.5.3.3. Bilateral Donors

Among the bilateral donors operating in Namibia, Germany – through GIZ – has been one of the largest funders of programs and projects that support climate change adaptation in Namibia. The following are some of the climate change adaptation projects and programs that are currently being funded by Germany through GIZ:

- Biodiversity Management and Climate Change (US$7.5m);
- Resource Mobilisation for Effective Implementation of the Biodiversity Strategy (US$3.13m);
- Bush Control and Biomass Utilisation (US$12.5m);
- Adaptation of agriculture to climate change in northern Namibia (US$7.5m);
- Community-based natural resource management (US$6.25m);
- SDG initiative (US$3.75m);
- Conservation and sustainable use of the Benguela Current large marine ecosystem (US$11m);
- Transboundary water management in SADC (US$17.76m);
- Sector support to combat desertification (US$7.9m); and
- Transboundary conservation and use of natural resources in SADC (US$10m).

Other bilateral donors include Finland (both to address bush encroachment) and UK Aid (for development of a climate financing strategy and program). Activities have also been scaled up between Namibian and

[6] Source: GEF website, https://www.thegef.org/country/namibia

foreign development financing institutions (DFIs) – predominantly DFIs from Europe – for private sector projects to mitigate and adapt to climate change.

4.5.4. Adaptation: Emerging Issues

This section focuses on some of the key issues emerging in Namibia's climate change adaptation space. The emerging issues that are covered in this section include adaptation in informal settlements, barriers to adaptation, enables and desired outcomes, novel approaches to adaptation and monitoring and evaluation needs. Each of these aspects are covered in the following sections.

4.5.4.1. Adaptation in Informal Settlements in Namibia

Namibia is undergoing a rapid and major transition from a rural-based society to one based largely in urban areas. This transition is most visible in rapid urban growth, especially in informal settlements that accommodate low-income families in shacks on the edges of towns. Namibia's urban areas now have some 140,000 households in informal settlements, a number that is likely to double over the coming 7 or 8 years (Weber and Mendelsohn, 2017). Projections are that the number of informal housing units in urban areas (i.e., urban shacks), in Namibia, will surpass that of formal housing units in urban areas as well as rural homes by 2025 (Figure 4.32).

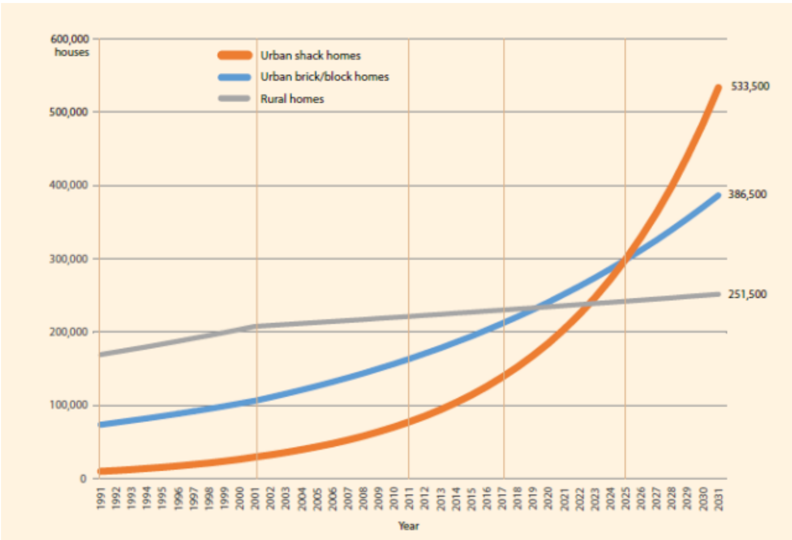


Figure 4.32 - Numbers of formal (brick or block) and shack homes in Namibia between 1991 and projected forward to 2031

Source: Weber and Mendelsohn, 2017

Climate change and climate variability is one of the key drivers of in-migration in Namibia. Rural households in Namibia are increasingly finding it difficult to generate income from subsistence agriculture (i.e., the main livelihood source in rural Namibia). This is because of climate change impacts, notably degraded lands, water scarcity, and rainfall variability, keep subsistence agricultural production very low, with little chance of having surpluses that could be marketed. As a result, most people in rural areas resort to moving to urban areas in search of livelihood opportunities. Most of the migrants from rural areas and small towns usually settle in informal settlements in urban areas. This results in the proliferation of urban shacks, one of the most prominent phenomena of the growth of major towns and cities, and potentially one of the most pressing future challenges of cities and towns in Namibia.

However, migration is one of the major drivers of informal settlement growth in Namibia. Other factors contributing to the development and growth of informal are the sheer number of people that need to be housed and provided with services and a lack of formal employment, but also mainstream urban policy that fails to address issues of informality or appreciate the cumulative consequences of poverty. Furthermore, another major reason for the expansion of informal settlements – and in such a disorderly manner – is that the formal land supply systems and markets do not serve the needs of low-income

Namibians. As a result, they have no option but to acquire land informally and to build informal homes. They are forced to become participants in the informal market of informal settlements.

Box 4.2 - Emerging Climate Change Vulnerability of Informal Settlements

The proliferation of informal settlements, particularly urban slums, is becoming a prominent phenomenon of major towns and cities in Namibia, and potentially one of the most pressing future challenges. Factors contributing to the development and growth of urban slums are the sheer number of people that need to be housed and provided with services and a lack of formal employment, but also mainstream urban policy that fails to address issues of informality or appreciate the cumulative consequences of poverty. Additionally, formal land supply systems and markets do not serve the needs of low-income Namibians. As a result, they have no option but to acquire land informally and to build informal homes. Low-income Namibians are forced to become participants in the informal market of informal settlements. Collectively these issues mean that urbanization in Namibia has mostly failed to bring about inclusive growth. Instead, urbanization is leading to the creation of clusters of deprived areas on the outskirts of towns and cities in Namibia. These deprivations lead to low adaptive capacity making the informal settlements highly vulnerable to the impacts of climate change.

Typical informal settlement housing structure in Namibia made out of corrugated sink

Source; Namibia Broadcasting Network (NBC)

As the challenges of urbanization collide with climate change impacts, settlements – especially informal settlements in urban areas – are becoming more vulnerable and progressively less able to deal with climate change risks. The low adaptive capacity of informal settlements in Namibia is driven by various and complex socio-economic processes related to the cultural, political, institutional, colonial contexts and demographic pressure, as well as specific high-risk zones susceptible climate change impacts. Furthermore, the low adaptive capacity of informal settlements can also be explained by a lack of understanding and political acceptance of urbanization and informality. Urbanization is complex and challenging, but should be embraced as a powerful and unavoidable process that represents an invaluable opportunity for development.

Improving the resilience of informal settlements to climate change impacts require policymakers and stakeholders to prioritize and manage urbanization challenges by planning settlements systematically, enabling concurrent, diversified economic development, investing in infrastructure and basic services, and addressing the deprivation levels. It also requires improving liveability, monitoring long-term risk and vulnerability factors, and carrying every resident along with their plans. In this regard, the urban management and planning function in major towns and cities needs to be strengthened to help them plan for inclusive growth and avoid certain situations, such as the emergence of more urban slums. Furthermore, government and municipalities should accept existing informality as a response to the housing backlog and resist a universal approach of informal eradication settlements. Rather, government and municipalities should provide the environment and services for informal settlements to become full-fledged, self-sustaining and dignified components integrated into the cities and towns.

A recent study on the growth of informal settlements in Namibia by Weber and Mendelsohn (2017), highlights some of the best practices that some towns and cities in Namibia. Weber and Mendelsohn (2017) contend that some towns and cities are taking control of the rapid growth of informal settlements. Towns take control by providing land and housing to low-income households at prices they can afford and properly planning and surveying townships that can one day be readily proclaimed. They also keep the cost of servicing land at a minimum at the beginning and gradually increasing it, so that the cost of land is low, but the land is upgradable over time; and allowing low-income residents to build houses, for themselves, at their own pace. Collectively, these interventions will not only allow government and municipalities to take control of the rapid expansion of informal settlements but also allow government and municipalities to address deprivations in informal settlements thereby making them resilient to climate change.

4.5.4.2. Existing Adaptation Barriers, Proposed Enablers, and Desired Outcomes

This section features barriers, enablers, and outcomes that, once addressed, could lead to large-scale positive impacts across sectors, people, households and political regions. They are of the nature that once a barrier is removed, the potential for a paradigm shift is unlocked and, coupled with other enablers and involvement of the private sector, civil society and community-based organizations, could lead to sustainability and environmental, social and economic co-benefits. The barriers identified are presented in Table 4.7. These barriers reflect key contemporary issues at global and regional levels, with relevance to Namibia. The barriers are also demonstrative of changes over time, of methods and approaches to deepen our understanding of the social and economic contexts of climate change, an example being social differentiation.

4.5.4.3. Approach for New Adaptation Initiatives

Since climate change adaptation initiatives are evolving from a sectoral approach to a community-based and settlement approach following the definition of settlements by IPCC, therefore:

- It is becoming imperative to consider youth, women-headed households, and vulnerable groups in the adaptation strategies to enhance relevance and commercial viability of community-based initiatives, e.g. agribusiness. Women-headed households represent 60% of total rural households, and they play an important role in local resources and livelihoods sustainability (social differentiation).
- Climate change adaptation investments at community-level can target the climate change vulnerable hotspots, as identified using the NCCVI results coupled with the characteristics of human activities for livelihoods and resource sustainability; and
- Adaptation assessments should seek to improve the identification of climate change and climate variability hazards and risks and match these with replicable and scalable successful and innovative adaptation strategies.

Table 4.7 - Identified Barriers, their enablers, and desired outcomes

Barriers	Enablers	Desired outcomes
Financial and economic risk context, National, regional, and local financial and economic risks associated with climate change are largely unknown by the private sector level. Some banks and NBFIs are engaged/ing in	• Include the Namibia Chamber of Commerce and Industry (NCCI), sector umbrella bodies, and civil society/ community-based representation in the NCCC. This could include the chamber of mines, the confederation of fishing associations, Namibia Association for Community-based Support Organizations	• Private sector, civil society and community-based groups are represented on the NCCC • National Climate Change and Business Cost-Benefit Analysis delivered with

Barriers	Enablers	Desired outcomes
climate-related investments and, availing climate-related finance. However, there is a need for a national financial and economic risk assessment using the NDCs as a departure point and for dialogue. The private sector, household, and individual understanding need to be improved critically to enable nation-wide grasp of the risks of climate change on the household, business, and national economies. A cost-benefit analysis was done for bush encroachment in Otjozondjupa region; if harnessed as a sustainable economic growth driver, nationally it is estimated to deliver a net economic benefit of US$124 million per year through viable business enterprises, not to mention other social and environmental co-benefits. This approach can be used a part of climate-related financial/ economic risk assessments.	(NACSO), and the Association for Local Authorities in Namibia (ALAN) and informal settlement representative bodies (e.g. Shack Dwellers Federation) • Conduct a National Climate Change and Business Cost-Benefit Analysis (CCBCBA) to identify specific risks and their mitigation measures inclusive of costs, and disseminate using contemporary media (infographics) and social media approaches; • The CCBCBA would include all primary and secondary sectors and, income-generating activities that are important to >55% of people living in rural areas. The CCBCBA can relate to rural-urban migration which is increasing annually and is in part induced by droughts and periodic floods • Based on current National Accounts data, relate the above CBA to the national accounts to enable projections of a "business as usual" vs. a climate-informed paradigm-shifting approach • Integrate climate change in Namibia's quarterly and annual Economic Reviews.	concrete recommendations to access climate finance and, to improve the regulatory and policy environments • Quarterly and annual economic reporting includes climate change risks, how they have been addressed and, how economic performance is impacted by climate change.
Regulatory and policy context. Namibia's policy environment is climate relevant to a large extent. However, there is a need for regulatory and policy instruments (both incentivizing and punitive) that promote investment in climate change adaptive and mitigating actions. The regulators and policymakers are critical for a transformation toward an enabling environment comprising of both incentivized and punitive (encouraging self-regulation to cost-benefit analysis, etc.) measures. The ultimate aim is initiative and self-regulation to mitigate short-medium term risks such that social, environmental and economic values of business and enterprise are protected and improved. The thrust should be food, water, and energy security, profitability, sustainable development, economic growth, and job creation.	• The National Climate Change and Business Cost-Benefit Analysis could include the review and analysis of climate-related business incentives and, punitive measures for climate change accelerating activities. The outcome could include a business community pledged to implement climate-relevant incentives and punitive measures that can be supported through appropriate regulatory and policy frameworks. • The CCBCBA could include a review of the NDCs, repackaging each as a viable business activity and relating the incentives and punitive measures where appropriate. Punitive measures must be positioned to encourage self-regulation by the private sector, based on the outcomes of the CCBCBA • Government endorses the CCBCBA outcomes and policy improvement recommendations for implementation as a Climate Change-and-Business Adaptation Financing Programme; • Improve the climate change financing and CBA understanding of all persons and functions in government dealing with budgetary and financial programming such that there is awareness of the sector-specific CBAs that can lead to implementation. This is particularly important to the Ministry of Finance and the National Planning Commission.	• CCBCBA and NDC derived pipeline of viable adaptation (and adaptation-mitigation) projects for financing presented as a Climate Change-and-Business Adaptation Financing Programme. This can form part of Namibia's overall Climate Financing Programme. • Capacity improved of all persons and functions in government dealing with financial management and budgetary planning • Each line ministry/ government function has access to their specific CBA outcomes that require financing to be realized;
Institutional and individual capacity context and the limiting availability and access to climate information could limit	• The CCBCBA outcomes and recommendations would provide great material for raising awareness about specific climate change risks	• Improved available and access to climate change information and data that

Barriers	Enablers	Desired outcomes
investments to adaptation. People need access to information in most-preferred formats and dissemination approaches (e.g. social media) and, most importantly related to their lives, livelihoods, business, and the economy. A critical minimum age can be defined such that children start a guided process of knowledge and concept building about climate change (see UNICEF's 2018 CLAC for Namibia). The youth at age 20 today are the adults at 2030 when the Paris Agreement targets are due. Individuals make up institutions and while lifelong learning that are profession and vocation specific is critical, the raising of knowledge and understanding of concepts about climate change, its risk and impacts, would build toward a climate-literate workforce.	and their observed and future impacts on people, business, the environment, and livelihoods • Furthermore, CCBCBA material can be packaged for inclusion in school, vocational and tertiary curricula to ensure ongoing and dedicated capacity development in Namibia for climate change • Package and disseminate success stories of existing successful adaptation practices (e.g., micro-drip irrigation and its expansion potential for food security) and use social media and radio for dissemination. Some of these already exist with government, bilateral and multilateral institutions (e.g. UNDP and GiZ), programs such as the GEF/UNDP Small Grants Programme (SGP) and within communities (Iipumbu Ya Tshilongo Conservancy) • Inform the public of contemporary issues of climate change about working conditions; e.g. the predicted increase of 1.5°C for southern Africa and the potential impacts of heat exposure on outdoor working conditions and indoors for informal settlement housing • Inform the public of concepts like Social Differentiation, how it relates to Namibia, and how it is or, can negatively impact our ability to raise resilience and adaptive capacities. Publicize potential ways to overcome such factors.	relates to business and peoples' lives and livelihoods • Successful climate change adaptation interventions are prioritized for replication and scaling up (see below for how activities can be prioritized); • Namibians are aware of the potential impacts on work due to a predicted 1.5°C temperature increase and viable mitigations are being explored solutions • Social Differentiation is mainstreamed in adaptation finance planning such that the right capacity and knowledge is harnessed, especially at rural levels for measurable improvements in resilience and adaptive capacities.
Scale and scope context is critical for a paradigm shift at national, regional, local and sector levels. There is a need to know what the current scale and scope is for replicating successful adaptation activities. Given the estimated burden of cost for adaptation in Namibia – US$670 million per year till 2030 – it is critical that food production innovations that show 5 - 10 year success are upscaled in volume and rolled out geographically where feasible. Similarly, sea and freshwater desalination, rainwater harvesting and reuse and, large-scale wastewater treatment and reuse have experience in Namibia and could be upscaled and rolled out. There are other examples of good practice resilience and adaptive capacity development that can be identified with development	• Identify successful and scalable resilience and adaptive capacity developments and, using the CCBCBA, plan for upscaling; • Activities that show potential for profitability, employment creation, wider economic development and adaptation-mitigation benefits (e.g., tackling bush encroachment) should be identified as priority and included in a climate financing program for Namibia • Paradigm shifting approaches, for example, indoor integrated agriculture-aquaculture systems[7] – such that a viable long-term shift in the way of doing business is mainstreamed. Such paradigm-shifting approaches can form part of revised regulatory and policy environment that encourages adaptation and mitigation and penalizes conflicting investments (e.g. fossil fuel-based energy use, water-inefficient agriculture, lack of rainwater harvesting systems where viable) • Implement a robust Monitoring, Verification, and Reporting (MRV) system for the CCBCBA-derived Climate Change-and-Business Adaptation Financing Programme. This would	• The prioritization of successful adaptation activities could be based on (a) effecting a paradigm shift; (b) measurable progress of improved adaptation and resilience (e.g., no of households adapted); (c) potential to impact large numbers of people, households or businesses and, (d) potential for a mitigation co-benefits for measurable CO_2 reductions; • Concrete recommendations to improve the regulatory and policy frameworks to enable private sector investment • Monitoring, Verification, and Reporting system in place and delivering pertinent data to monitor progress and, to leverage additional finance,

[7] E.g. of indoor production of tilapia and using effluent water as fertilizer for crop cultivation.

Barriers	Enablers	Desired outcomes
partners and mainstreamed for public uptake.	enable tracking quantitative indicators for progress and reporting but, more importantly, would generate the data for use to leverage financing, partnerships and cleaner technologies for a sustainable paradigm shift.	partnerships, and technology.

The analyses of climate change adaptation actions in Namibia shows that they are primarily systems- and sectoral-based approaches. It is suggested that the subsequent climate change adaptation actions and solutions emphasize upscaled transformative approaches that are multidimensional. That is, integrating health, livelihoods, poverty and food security and rural-urban migration and disaster risk management. Such an approach will leverage the impacts of adaptation investments. For instance, adaptation actions in food security will also have impacts on health, poverty and rural-urban migration. Consequently, proposed upscaled and integrated adaptation approaches should have short-term social safety goals and long-term adaptation and resilience targets. The following options are proposed:

- Option 1 - Coastal infrastructure buffering and renewable energy powered desalination plants with intermittent linear food production systems; integrated aqua-agriculture systems; and buffering health, education and transport infrastructure in disaster-prone areas.
- Option 2 - Water-energy-food-health nexus in meat value chains particularly in the northern communal areas (NCAs), desalination using renewable energy, rainwater harvesting at large scale and food production resilience by resilient crops and indigenous livestock breeds with strong focus on social differentiation, intersectionality, and adaptive capacity.
- Option 3 – Test viability of marine aquaculture concept as a buffer to shifting fish biomasses and additionally, package and upscale local coping and resilience mechanisms for droughts, floods, fires, food security, and multi-dimensional poverty.

Added opportunities exist in the current integrated and community-based projects funded by AF, BMZ, GCF, and the GEF:

- Namibia Integrated Landscape Approach for Enhancing Livelihoods and Environmental Governance (NILALEG) to eradicate poverty (US$10.8m);
- Community-based projects under the UNDP Small Grants Programme to raise resilience and adaptive capacities (assuming five grants per year over five years = US$1.25m).
- Empower to Adapt: Creating Climate Change Resilient Livelihoods through Community Based Natural Resource Management (CBNRM) in Namibia (US$10m).
- Improving rangeland and ecosystem management practices of smallholder farmers under conditions of climate change in Sesfontein, Fransfontein, and Warmquelle areas of Namibia (US$10m).
- Climate Resilient Agriculture in three of the Vulnerable Extreme (CRAVE) northern crop-growing regions (US$10m).
- The "Pilot Rural Desalination Plants Using Renewable Power and Membrane Technology" Project in Namibia (US$4.9).
- Conservation and sustainable use of marine biodiversity in the Benguela Current Marine Ecoregion (US$10.9m).
- Realizing the Inclusive and Sustainable Development in the BCLME region through the Improved Ocean Governance and the Integrated Management of Ocean use and Marine Resource (US$10m).
- Enhancing Climate Change Resilience in the Benguela Current Fisheries System (US$4.7m).

The above projects and programs represent a funding envelope of over US$70 million for the period 2015 to 2020/21. Many of these interventions, particularly the GEF financed ones have potential for private sector participation, such that the grant funding can serve as equity contributions for communities and, used to leverage additional private financing for viable and sustainable business options.

4.5.4.4. Monitoring and Evaluation

Monitoring, evaluation, and reporting on progress on the implementation of the NPCC and the NCCSAP has numerous challenges in Namibia. These challenges including a lack of capacity, complex metrics, and how to report on adaptation activities being implemented across widely varied sectors, ecosystems and at different scales, local to national. Namibia needs to take the opportunity to invest in Monitoring & Evaluation (M&E) systems to improve its national adaptation planning processes and then use the M&E system for reporting its progress to the UNFCCC through the National Communications.

Given that climate change has been mainstreamed in the NDP5, opportunities therefore exist for the MET to leverage M&E systems within the reporting framework of the National Development Plan to track progress. Furthermore, it is recommended that, as far as possible, Sustainable Development Goals (SDGs) indicators, are adopted and aligned with the goals and targets of NCCSAP. Collectively, these suggestions will mitigate some of the reporting constraints highlighted above.

Furthermore, the constructed NCCVI can also be used for monitoring, evaluating, and reporting on climate change vulnerability across human settlements in Namibia. Since the human settlement sector is closely linked to other sectors such as agriculture, water and health, the NCCVI can also be used a proxy indicator for the vulnerability of these closely linked sectors. Additionally, the NCCVI can also be used as a tool for monitoring the effectiveness of adaptation actions. For instance, the impact of adaptation action can be analysed by comparing the values of the NCCVI for a given settlement/constituency before and after the action.

4.5.5. Conclusion and Recommendations

Climate change adaptation has been project-based for the past ten years and coordinated from a small secretariat in the DEA, MET. It is difficult to measure progress made in respect of climate change adaptation (CCA) without baselines as reference points for inference of success of the implemented actions and activities. This warrants a further strengthening of the CCA planning framework for enhanced coordination and implementation. Mainstreaming of CCA in sector policies, plans, and programs and decentralized at sub-national levels requires a concerted effort if Namibia's economy is to become climate resilient by 2030. Financial barriers limit the effectiveness of the CCA actions country-wide and the provision of extension services in rural areas to increase the agricultural capacity of communities. Financing of CCA actions are project-based and funded by international development partners without a coordinated and consistent system to follow-on quantitatively. Efforts have been recently to include climate change issues in the national development planning framework to measure progress on the results of the investments.

The climate change resource centre and centralized database has not yet been established for the coordination of climate change observation systems. The latter is particularly needed if meteorological data are to be processed for the establishment of an early warning system for preparedness to extreme events such as drought and flooding in the north-central regions and the north-eastern floodplains. Data management for the crop sub-sector and CBNRM activities in conservancies and community forests have to be updated regularly.

Ecosystem changes have not been monitored regularly, but the review of the National Core Environmental Indicators in 2015 developed through the Environmental Monitoring and Indicators Network (EMIN) and used in the first Integrated State of Environment Report in 2006 will provide the necessary impetus for regular monitoring and evaluation of ecosystem changes. The Benguela Current Commission (BCC) has produced the second State of the Marine Environment in 2014. The use of the ecosystem-based approach in fisheries management with its modules on environment, social, governance, and ecosystem health will improve the State of the Marine Environment reporting. The National Core set of Environmental Indicators was adapted for the coastal zone in 2015 based on the Pressure-State-Response (PSR) Framework developed by OECD. Climate change features in this indicator framework, albeit without sufficient coverage. Climate change and their impacts ought to be monitored relative to baselines on ecological, social, economic and governmental conditions supported by a good indicator framework.

Namibia can access financing from climate investment funds, and recently developed a country strategy for the GCF that advocates for a paradigm shift towards low-emission and climate-resilient development pathways. Readiness grant has been provided by the GCF to establish a National Designated Authority (NDA) to make the link between the Namibia government and the Fund. The NDA will be able to access further funds from the GCF to implement the national climate change adaptation framework. Namibia will continue receiving multi-lateral and bilateral support through international and regional development partners for climate change mitigation and adaptation. There is, however, an urgent need to strengthen collaboration between government and civil society for synergistic results given the scarce financial and human capital.

5. Mitigation

5.1 Introduction

Non-Annex I country, initially had no obligation to reduce their GHG emissions as signatory Parties to the Convention. Given the dire situation, namely the continued increase in GHG emissions in the atmosphere and IPCC projections for the global warming to exceed the 2 ^{o}C level by 2050, decisions 1/CP.19 and 1/CP.20 were adopted by the Conference of the Parties, the goal being to limit warming to less than 1.5^{o}C. In conformity with these decisions, the Republic of Namibia prepared and submitted its Intended Nationally Determined Contributions (INDC) to the United Nations Framework Convention on Climate Change. Furthermore, the Government of Namibia has reviewed and updated various policies and strategies to change its development agenda into a green low carbon economic pathway within the framework of the SGs. Namibia has embarked on various projects and activities aiming at curbing GHG emissions and increasing its sink capacity. This mitigation analysis updates the previous one presented in the NC3 by addressing options which present the highest potential for mitigation based on the latest emissions estimates, with base year 2010 up to the 2035-time horizon.

5.2 Assessment method

The major principles guiding this mitigation assessment rest on the International, regional and national contexts:

At the international level, it is primarily the decisions of the COP of the UNFCCC that obliges Namibia as a a signatory Party to implement them towards meeting the objectives to limit GHG emissions as per Article 2 of the Convention, especially the latest Paris Agreement that has also been ratified by the country;

In the region, some issues such as the import of electricity from the South African Power Pool, notably from ESKOM of South Africa and the sharing of water from the transboundary rivers with neighbouring Angola. ESKOM is presently facing serious problems to meet the electricity demand of South Africa itself and may not be able to guarantee a stable supply to Namibia for guaranteeing energy security and the normal development of the country. Additionally, ESKOM electricity generation is from coal that must be phased out within the context of the Convention. Hence, Namibia has decided to transition from imports to indigenous production of electricity from renewable resources in the medium and longer term to ensure energy security for its normal development while supporting the COP and its agenda to adopt a low carbon development agenda. As well, the sharing of water from the transboundary rivers between Namibia and Angola plays a crucial role in future further development of hydroelectricity generation and irrigated crop production for ensuring food security; and

Nationally, climate change is already posing serious threats to the country. Albeit, enhancing the resilience of the population to climate change impacts, Namibia's strategy is to reduce emissions while enhancing sinks within its mitigation programme. The objective is to explore mitigation within all possible sectors of the economy.

This mitigation analysis is thus based on these principles. It integrates the projected socio-economic conditions of the country with the implementation of mitigation measures as per the sectoral development strategies within a sustainable development agenda. Additionally, the key category analysis for the level and trend assessments of the last inventory year for the time series 1991 to 2015 have been taken into consideration as well as other factors. The major issue is the transition from importing electricity to generating same from indigenous sources

A Business as usual (BAU) scenario has been developed for all categories and sub-categories assessed for their emissions and removals in the latest GHG inventory to provide for the carbon intensity of the country under the development path dictated by the situation in 2010, the base year for this assessment. Activity areas offering the highest potential for action based on the guiding principles and other factors enumerated above were then assessed for their mitigation potential by comparing emissions or removals of the different measures identified within the category or sub-category to the BAU scenario. Since the well-developed and agreed strategies within current development plans are to the 2030 tome horizon, this mitigation analysis covers the period up to the year 2035. GHG mission projections have been done on estimates obtained from the compilation in the inventory time series for the BAU scenario and on the evolution of the variables usually responsible for emissions or removals. Some of these variables are fuel demands to meet the future energy requirements, projected number of vehicles, expected land use changes and amount of waste generated. Projections for industrial production is associated with GDP growth rather as it is such a dynamic sector with new industries starting/ending operations as the country progresses. For those sectors directly linked with demographic growth, the projected population and urbanization rate have been retained for future years.

Once the activity data have been generated for the different options such as fuel combusted, waste produced, wood removed or area reforested amongst others, these were either fed in the IPCC 2006 software to compile emissions or removals for the year being assessed. Alternatively, emissions or removals were compiled using excel spreadsheets. The difference between the BAU and mitigation scenarios emissions or removals of the category under assessment gives the emission abatement or sink enhancement value of the potential measure. If several measures can contribute to mitigation in a single category, their values were added to provide for the full mitigation potential of that activity area. The emissions and removals from all categories were then summed to give the abatement potential at the different time steps under consideration for the sectors and finally at the national level.

5.3 Scope of the assessment

All activity areas concerned with emissions or removals in a country can be targeted for mitigation analysis. However, this is very resource demanding and very often, it is not worth evaluating the marginal and minimal contributors of GHGs for their mitigation potential as it is not cost effective. Moreover, priority changes with time and development of a country which results in activity areas gaining or losing importance as contributors of GHGs. Thus, the exercise should be kept dynamic and the ones offering the highest mitigation potential, coupled with a high success rate for implementation, were treated with priority. Based on this principle and taking the level and trend assessment from the KCA, the electricity generation, road transportation and LAND categories were prioritised for the assessment. Due to its importance in relation to health and sustainable development, the waste sector also has been considered.

5.4 Socio-economic scenarios

5.4.1. Population size and growth

For this exercise, the population projections from the National Integrated Resource Plan (NIRP) has been preferred for adoption because all electricity demands have been based on them and also since this activity area is highly influential on other issues such as use of biomass for residential purposes. The adoption of this population projections ensures consistency in the assessment. The NIRP worked on a low, medium and high variant for projecting the population. Throughout the study, the medium variant has been adopted. The population stood at 2.077 million in 2010 to increase by about 1.9% up to the year 2015. Thereafter the rate of increase adopted is 1.8% to 2027, 1.7 to 2033 and 1.6% to 2035. Based on these growth rates, the population is projected to be 2.505 million in 2020, 2.733 million in 2025, 2.962 million in 2030 and 3.185 million in 2035. The projected population for the period 2010 to 2035 is given in Figure 5.1.

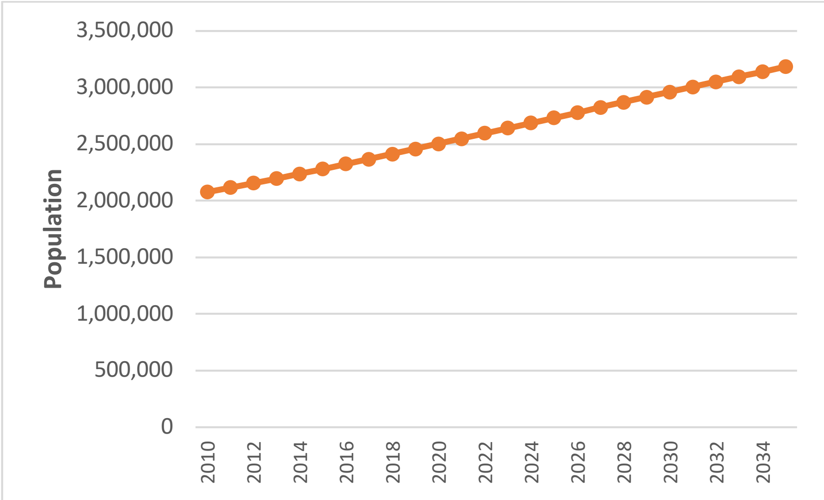


Figure 5.1 - Namibia population statistics and projections (2010-2035)

5.4.2. Urbanization

Between 1991 and 2011, the increase in urban population largely outpaced the rural component of the total population. This rapid rise in the urban population is largely due to the continuous migration of the rural youth to seek employment in the prosperous towns.

There is no doubt that the rural-urban movement will continue to amplify over time, as, since the early 2000s, it has been government's vision and policy to promote the country as a highly industrialized and highly urbanized one. In the Vision 2030 document published in 2004, it is estimated that by 2006, the urban population of Namibia will reach 43%. Subsequently, for the years 2010, 2020 and 2030, the then projected fraction will reach 50, 60 and 75% respectively.

A medium-term profile (annual projections until 2035) for urbanization was developed based on past recorded trends, initial projections as set out in Vision 2030 and NSA population projections of 2011. The main features are an urbanization rate of 1% year on year for the period 2010 to 2030 and thereafter by 0.75% up to the year 2035. Thus, by 2030 the urban population is projected to be 62% of the total population, bringing the number of persons living in towns to 1.836 million. This represents an increase of 0.926 million over the year 2010. In case the projected urbanization level reaches 65.8% in 2035, this fraction of the population will stand at 2.094 million. The latter number will be more than twice that of 2010 (Figure 5.2).

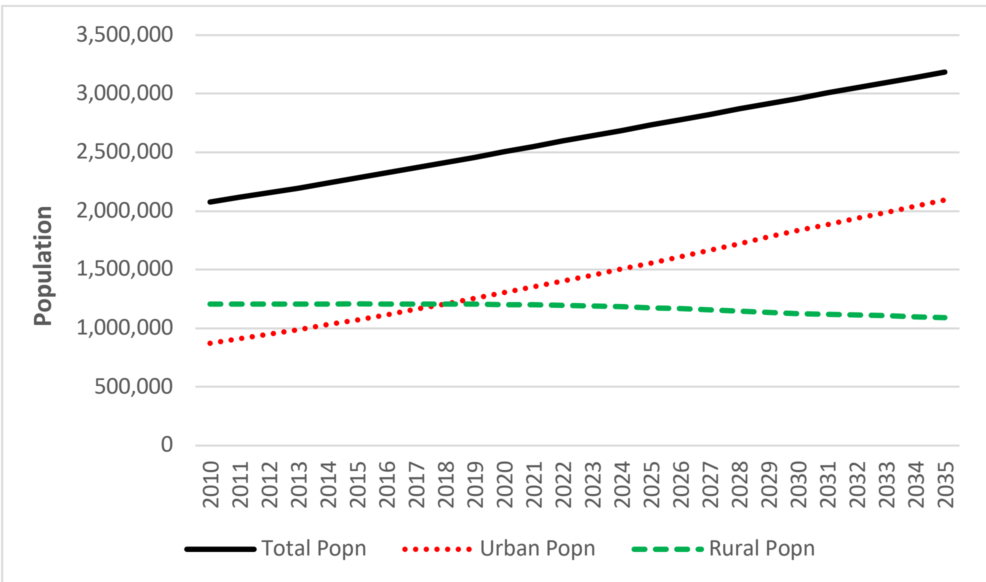


Figure 5.2 - Urbanization level in Namibia

5.5 National mitigation potential

5.5.1. BAU National level

Emissions stemming from the BAU scenarios for the base year 2010 and the projections for 2025, 2030 and 2035 are given in Table 5.1. Relative to the year 2010, the country will increase its sink capacity by the year 2025 after which it will regress. The sink capacity is projected to increase from -83,999 in 2010 to -94,448 in 2025 and decrease to -87,039 in 2030 and -76,015 in 2035. The AFOLU sector is the driver of this situation with the sectors Energy, IPPU and Waste being emitters. Emissions increases for these three sectors over the study period.

Table 5.1 - Emissions (Gg CO2 –eq) under the BAU scenario for the years 2010, 2025, 2030 and 2035

BAU	2010	2025	2030	2035
National emissions	**-83,999**	-94448	-87039	-76015
Energy	5648	9999	11574	13328
IPPU	303	1212	1398	1596
AFOLU emissions	-90,085	-105,891	-100,292	-91,279
Waste	135	232	281	340

5.5.2. National mitigation potential Emission Reductions only

Different measures have been evaluated for the Energy, AFOLU and Waste sectors as detailed further down. For summing up to obtain the national mitigation values at the different time horizons, the best scenarios were chosen. The abatement potential (Gg CO_2-eq) at the national level, when compared with the BAU scenario, and the contribution from the different sectors evaluated are presented in Table 5.2.The mitigation potential summed up to 3804, 10,144 and 20,889 Gg CO_2-eq in 2025, 2030 and 2035 respectively.

Table 5.2 - Mitigation potential (Gg CO2-eq) for the years 2025, 2030 and 2035

Year	Energy	IPPU	AFOLU	Waste	Total
2025	3,665.2	43.8	-28.5	123.1	3803.6
2030	5,612.6	112.8	4,254.3	164.3	10,144.0
2035	7,111.0	169.8	13,395.0	212.8	20,888.6

When evaluating the final potential contribution at the national level, it depends on whether the country is a sink or emitter as this may change the perspective and understanding. Hence, both alternatives are presented in Table 5.3. Expressed relative to the net national sink capacity, the mitigation potential represents 4, 12 and 27 % of the sink capacity under the BAU scenario of the respective year under assessment. That is under the mitigation situation, the sink capacity increases by these levels. When viewed with respect to total national emissions, the mitigation potential is 8, 24 and 39% for the years 2025, 2030 and 2035. That is, under the mitigation situation, this represent the level of reduction in emissions. In fact, these are the potential mitigation contribution of the country for the three time steps for the options assessed.

Table 5.3 – Total and % reduction in sink capacity and emissions

Sector	2025	2030	2035
Net National sink capacity	-94447	-87039	-76014
National emissions only	35,178	42,585	53,610
Total reductions	**3,804**	**10,144**	**20,889**
% reduction sink capacity	4	12	27
% reduction emissions	8	24	39

5.6 Energy sector mitigation assessment

In Namibia, emissions from the Energy sector stems only from Fuel Combustion as there exists no activities to generate fugitive emissions and emissions from carbon dioxide capture and storage or transport. Hence, the mitigation assessment has stressed on the Fuel Combustion categories that are projected to be the significant emitters in the future. These are Energy Industries - Electricity generation, Manufacturing – Other Manufacturing, Transport – Road Transportation and Other Sectors – Residential. These are further detailed below.

5.6.1. Energy Industries - Electricity generation

Namibia electricity generation is dominated by imports from the SAPP, with the major share supplied by ESKOM of South Africa. In fact, in the base year 2010, Namibia imported 67% of its electricity and generated the remaining 33% for a demand of 3,767 GWh. By 2015, the share of imported electricity was at 65%.

NamPower, the national utility company, operates three main businesses, generation, trading and transmission of electricity. Its domestic power sources are the Coal fired Van Eck Power station outside Windhoek (120MW), the hydroelectric plant at Ruacana Falls in the Kunene Region (332MW), the Stand-by diesel driven Paratus Power station (24MW) at Walvis Bay and the Diesel plant of Anixas (22.5MW). With a peak demand of 535MW in June 2015, the internal resources are clearly not sufficient to meet demand.

5.6.2. Energy Policy and strategy

The 1998 White paper on energy policy outlined that Government aimed that at least 75% of electricity generation would be from internal sources by 2010, but this goal has not been met as 67% of the electricity demand was still imported in that year.

The Namibian energy policy to the 2050 horizon (2007) used in economic and demographic projections to chart the roadmap, with focus on the level of engagement of the Namibian Government and the level of cooperation between Namibia, regional and international Governments and organizations, charted the future strategy for the energy sector. The production of energy was confined to the electricity and biomass fuel sectors with a total capacity of 400 MW. Fossil fuel imports account for two thirds of the country's energy supply.

5.6.3. NIRP and forecast assumptions

Based on the Energy policy, the ECB completed the National Integrated Resource Plan (NIRP) to cover the next 20 years in April 2013. The NIRP was revised in 2016 to suit the national, regional and international contexts. Guiding principles are reduction of emissions in line with the Paris Agreement, difficulties experienced by ESKOM to meet demand in South Africa and export commitments, and the national strategy to generate electricity from indigenous resources. Sales recorded and forecasted for the period 2014 to 2035 is presented in Table 5.4. As expected, there is a steady increase in the figures to meet the increasing demand for development.

Table 5.4 - Sales forecast for period 2014 to 2035

Year	Low Sales (GWh)	Reference Sales (GWh)	High Sales (GWh)
2014	3,184	3,184	3,184
2015	3,387	3,402	3,413
2016	3,692	3,728	3,755
2017	3,927	3,998	4,050
2018	4,099	4,201	4,311
2019	4,196	4,333	4,556
2020	4,320	4,483	4,789
2021	4,461	4,647	5,001
2022	4,572	4,784	5,163
2023	4,688	4,927	5,334
2024	4,823	5,091	5,529
2025	4,966	5,265	5,735
2026	5,115	5,446	5,951
2027	5,280	5,647	6,189
2028	5,445	5,849	6,432
2029	5,616	6,060	6,685
2030	5,795	6,281	6,953
2031	5,980	6,508	7,227
2032	6,137	6,711	7,480
2033	6,337	6,959	7,783
2034	6,517	7,190	8,073
2035	6,733	7,461	8,407

5.6.4. Electricity generation action plan

For the purpose of this assignment, the NIRP2016 which has been worked out up to the year 2035 has been considered. The generation scenarios in this plan have been developed based on a series of assumptions and using probabilistic simulations. The scenarios have also been ranked based on qualitative multi-criteria, namely initial capital investment, reliance on import, use of renewables, location concentration, operating complexity, and indigenous resources. Out of the 11 generation expansion scenarios of the NIRP (2016) detailed in section 6.3 of the plan, the four with the highest share of renewables in 2035 within the mix of fossil and renewable sources were assessed for their mitigation potential.

The main features of the four scenarios as laid out in the NIRP are:-

- ***Ruacana Hydro plant***, (Commissioned in 1978 with 3 X 80 MW hydro generators and a fourth unit of 92 MW commissioned in 2012 for a total capacity of 332 MW. An average energy output of 920.0 GWH, Table 2-2, P 9.

- ***Van Eck Coal Plant,*** (4 X 30 MW commissioned in 1973. Output limited to only 60MW due to ageing and burning only 3500 tons of coal weekly to stay within environment norms and limits, P 9. Heat Rate of 17569 kJ/kWh.

- ***Anixas Diesel,*** (3 X 7.5 MW started operation in July 2011. Heat rate 9040 KJ/KWh. , This station benefits from new and proven technology which has a higher efficiency and reliability, and less emissions and noise than older power stations of its type.

- ***Imports*** from EDM Mozambique (30 MW hydro short-term supply contract reviewed annually, ESKOM South Africa (200 MW supplement until 2016 only), ZESCO Zambia (50 MW 2010 to 2020. at 92% capacity factor), ZESA Zimbabwe (150 MW from 2008 to 2014 only), and STEM South Africa (Short term).

- ***Renewables,*** Solar PV and Wind are assumed at 30% capacity factor average annually and CSP assumed at 30 to 70%.

- ***Biomass gasification,*** as from 2012 and will grow further till 2050 with the harvesting of invader bush.

- ***Natural Gas,*** the Kudu 2 X 200MW gas project will be available for only 15 years (lifetime of the gas field) and end in 2032.

5.6.5. Mitigation assessment

5.6.5.1. Business as Usual scenario

For the BAU scenario, the electricity demand was adopted from the NIRP 2016 for the 2020, 2025, 2030 and 2035-time steps but discounting 10% as losses on the grid. The national fuel mix of the base year 2010, consisting of hydro, coal and fuel oil was used to meet the forecasted demands. It is assumed that imported electricity is generated from coal, the case for the main supplier ESKOM, for all time horizons for consistency purposes because if the imported electricity is not considered, then the eventual mitigation assessment will not stand. The fuel mix of 2010 consisted of 32.7 % hydro, 67% coal, assuming imported electricity is generated with this fuel, and 0.3% fuel oil. The fuel mix of 2010 is used for the forecasted years. The amounts of fuel estimated for the fuel mix was calculated and emissions were then computed using the IPCC 2006 software. CH_4 and N_2O were converted to their CO_2-eq using the same GWPs adopted for the inventory, that is those from the SAR.

The demand increased (Table 5.4) from 2010 to 2035 representing increments of 73% to 2025, 106% to 2030 and 145% to 2035. Emissions increased from the base year value of 2,760 Gg CO_2-eq in 2010 to 4,899 in 2025, 5,844 in 2030 and 6,942 in 2035. This drastic increase over time is due to the phasing out of imports of electricity.

Table 5.5 - Electricity demand (GWh) and emissions for the base year 2010 and assessment years 2025, 2030 and 2035

Source of electricity	Electricity demand forecasted (GWh)				
	2010	2020	2025	2030	2035
Hydro	1,247	1,833	2,154	2,569	3,052
Coal	94	138	162	194	230
Fuel oil	13	19	22	26	31
Imports	2,462	3,620	4,252	5,073	6,026
Total	**3,816**	**5,610**	**6,590**	**7,862**	**9,339**
Emissions (Gg CO2-eq)	**2,760**	**4,170**	**4,899**	**5,844**	**6,942**

5.6.5.2. Mitigation scenarios

The energy supply-demand balance exercise from the NIRP (2016) for all scenarios was adopted and the amounts of fuel by source calculated. The firm energy supply was considered as being generated from solar PV, wind, biomass and coal with the latter being phased out almost totally when imports ceases in 2024 and most coal plants retired in 2025. Hydro is mainly used to meet the peak demands. Biomass from the invader bush is calculated as being sustainably produced and harvested over time. All imports cease as from 2024 and only renewables are added as from the year 2020 onwards till 2035.

The NIRP (2016) is a low-cost scenario mainly apart from other factors of national importance, but this criterion has not been considered when choosing scenarios for assessing their mitigation potential. Instead, the level of penetration of renewables has been the determining factor since the objective is to reduce emissions of GHGs and the country's strategy is geared towards increasing the share of renewables in the electricity generation sector to 75% in the medium term. All scenarios were assessed for their fuel mix over the different time steps to meet the national demand forecasted and the 4 scenarios having the highest share of renewables in 2035 were selected for evaluating their mitigation potential compared to the BAU scenario. They are scenarios 4, 5, 8 and 10 of the NRP (2016). The share of the different energy sources is presented in Figure 5.3 for the 4 mitigation and BAU scenarios for the three-time steps as the additions and phasing out of generation plants become effective. The increase in the share of renewables comprising hydro, solar, wind and biomass can be easily depicted in Figure 5.3. The complete phasing out of electricity imports in all the scenarios by 2024 is also integrated.

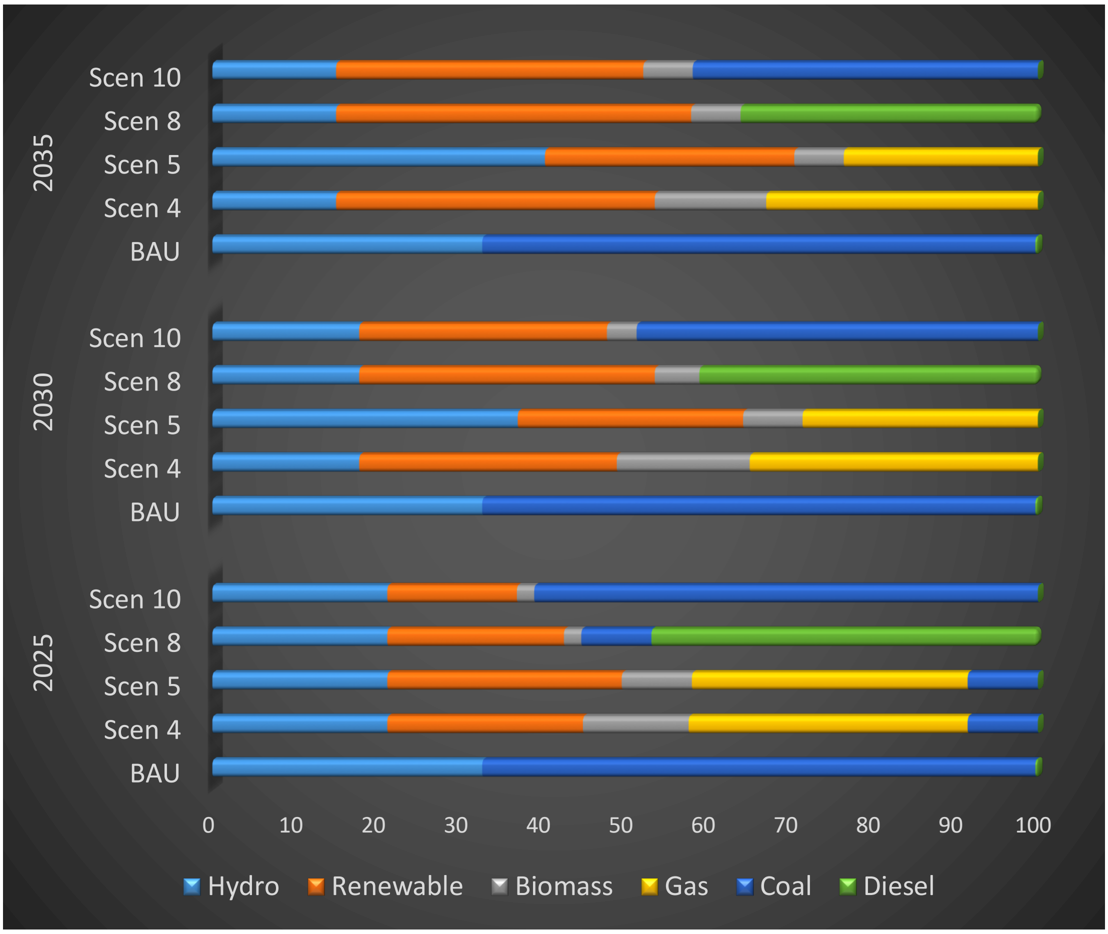


Figure 5.3 - Share of different energy sources for the years 2025, 2030, 2035 and BAU scenarios

5.6.5.3. Emission estimates

The fuel amounts derived from the electricity demand of the various scenarios and BAU were fed in the IPCC 2006 software to compute emissions. The difference in emissions between the BAU and each individual mitigation scenario provides its abatement potential. This exercise has been performed for the 2025, 2030 and 2035-time horizons and compared to the BAU scenario with 2010 as base year.

Emissions and mitigation potential of the four scenarios compared to BAU are given in Figure 5.4 to 5.10. Under the BAU scenario, the emissions will stand at 4,899 Gg CO_2-eq in 2025, 5844 Gg CO_2-eq in 2030 and as high as 6,942 Gg CO_2-eq in 2035. The mitigation scenarios assessed emitted in between 1,523 to 4,450 Gg CO_2-eq in 2,025, 919 to 4,240 Gg CO_2-eq in 2030 and 902 to 4,339 Gg CO_2-eq in 2035.

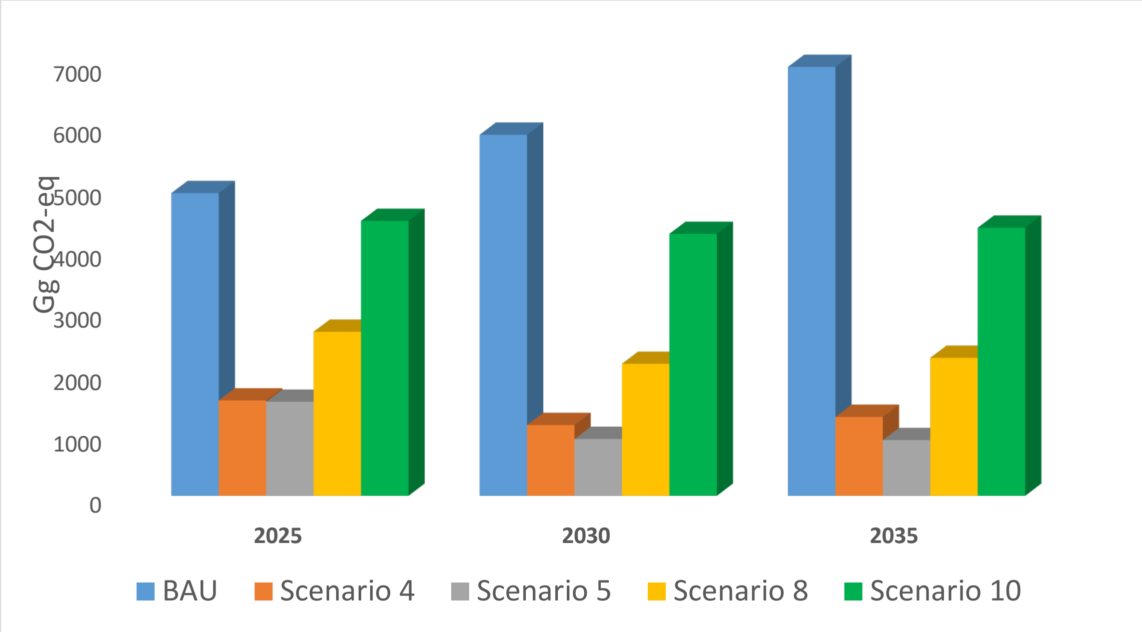


Figure 5.4 - Emissions (GgCO2-eq) for BAU and mitigation scenarios

These emissions represent a varying range of abatement potential (Figure 5.4) as per the energy mixes used in the different scenarios (Figure 5.3). Emissions reduction potential for the 4 scenarios are provided in Figure 5.5. Scenarios 4 and 5 offer the highest mitigation potential for all time steps. The reduction in the emissions for scenarios 4 and 5 amounted to 3,356 and 3,376 Gg CO_2-eq in 2025 as shown in Figure 5.5. The mitigation potential increases to 4,699 and 4,925 Gg CO_2-eq in 2030 for the same scenarios to reach 5,665 and 6,040 in 2035 as the level of renewables increases in the fuel mix of these scenarios. For the same time steps, scenario 8 showed an intermediate mitigation potential with 2,244 Gg CO_2-eq in 2025, 3,708 Gg CO_2-eq in 2030 and 4,709 Gg CO_2-eq in 2035. The worst case, scenario 10 offers a potential reduction of only 449, 1,604 and 2,603 Gg CO_2-eq in 2025, 2,030 and 2035 respectively.

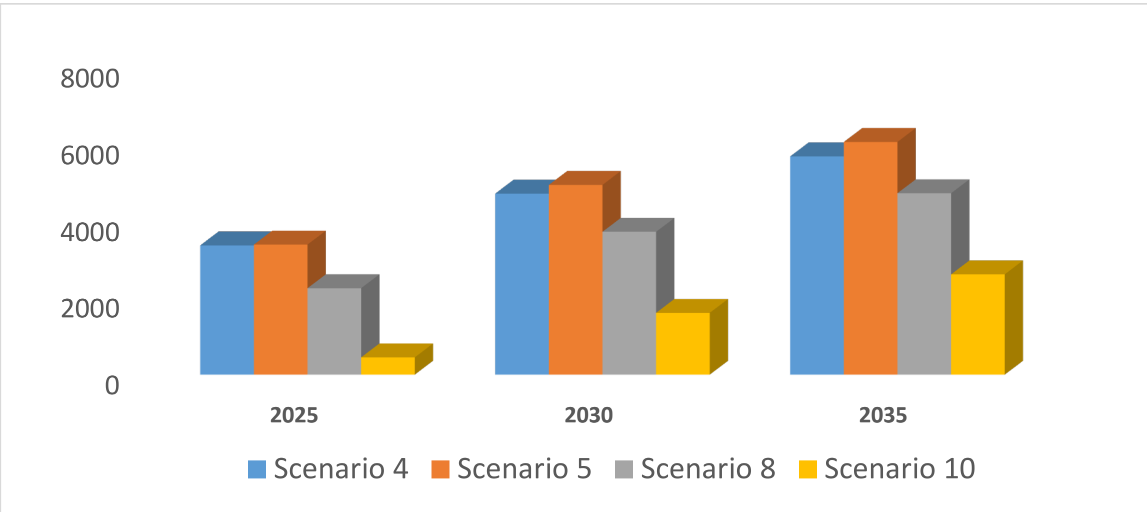


Figure 5.5 - Emission reduction (GgCO2eq) of mitigation scenarios compared to BAU

Compared to the BAU scenario, the magnitude of mitigation potential varied from 9 to 69% in 2025, 27 to 84% in 2030 and 37 to 87% in 2035 (Figure 5.6). These ranges corresponded with renewables contributing respectively between 39 to 58% in 2025, 51 to 71% in 2030 and 58 to 76% in 2035. These results can be depicted in Figure 5.7.

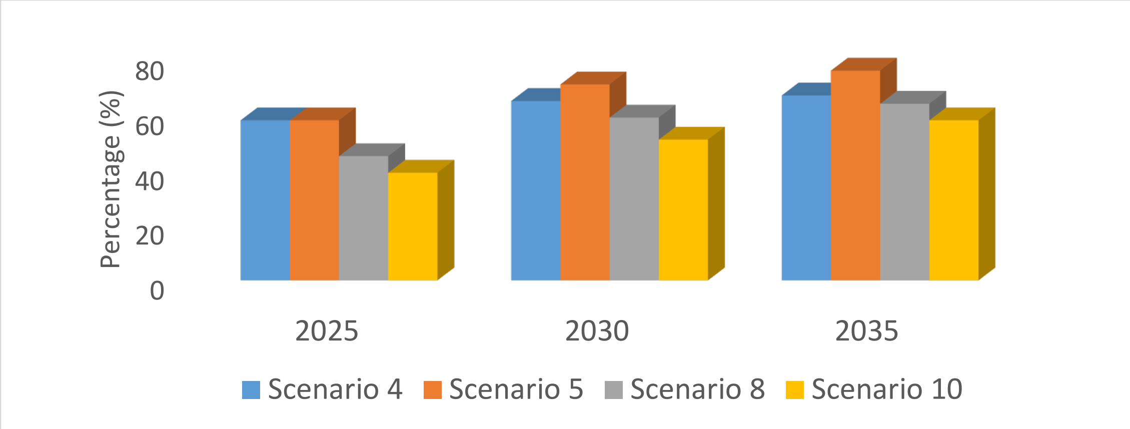


Figure 5.6 - Percentage emissions reduction for the 4 scenarios for 2025, 2030 and 2035

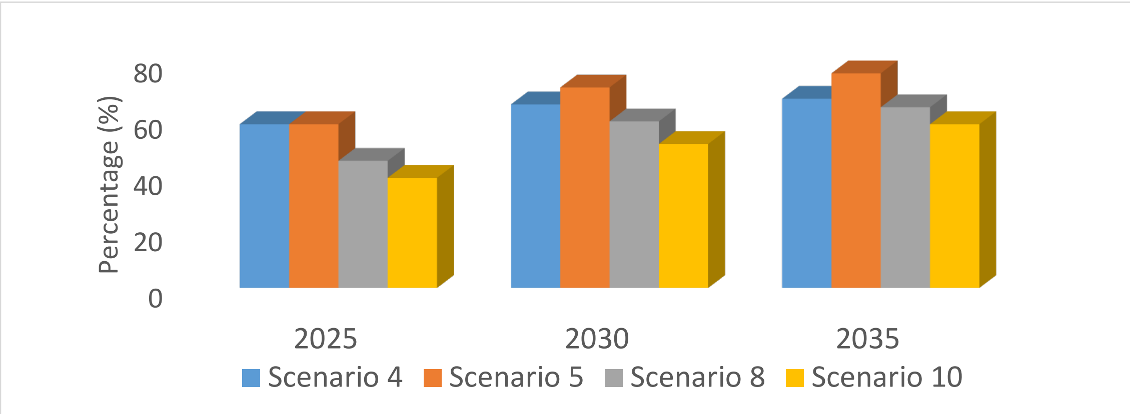


Figure 5.7 - Percentage renewables for the 4 scenarios for 2025, 2030 and 2035

5.6.6. Road transport mitigation assessment

5.6.6.1. Description of sector

Road transportation is the dominant mode of Namibia's transport system for both passengers and goods. In 2010, there was a total of 249,421 vehicles, all classes confounded. This fleet increased by 95,572 vehicles between 2000 and 2010 indicating an average growth of about 5% annually. This trend has been maintained to project the number of vehicles up to the year 2020 for the BAU scenario. The fleet is then projected to increase by 3% annually to 436,893 vehicles from the year2020 to 2025, by 2.6% annually till 2030 to reach 493,940 vehicles and by 2.6% each year up to 2035 to 550,987 vehicles.

The transport sector consumes more energy than any other productive sector of the Namibian economy. Liquid petroleum fuels for transport constituted over 70% of Namibia's total energy demand. This is somewhat distorted and is explained by the fact that Namibia uses only minimal amounts of fossil fuels in electricity production as it imports that commodity. In 2010, road transport consumed 333,000 tons of gasoline and 361,000 tons of diesel. These volumes are expected to increase by the same percentage as that adopted for projecting the number of vehicles. The change from gasoline predominance in the energy profile to diesel has been perceptible for some time with changes in vehicle technology; higher energy intensity of that fuel and its lower cost at retail.

5.6.6.2. The Business as usual Scenario

The BAU scenario for the road transport sector has been developed based on the socio-economic scenarios described earlier. It has thus been assumed that light passenger motor vehicles will continue to penetrate the market and remain the predominant means of passenger transport as will be light goods vehicle for freight transport. It has as well been assumed that the GDP growth with its resulting improvement in the standard of living of the population coupled with government's vision to propel

Namibia into the cluster of developed countries will spur the mobility needs for commuting more and over longer distances. To that effect, estimated annual vehicle kilometre run has been kept almost constant in spite of the fact that the projected increase in the number of such vehicles, as compared to the year 2010 is by an average of 3.2% annually up to the 2035 time horizon. The past and estimated vehicle population for the years 2025, 2030 and 2035 is provided in Table 5.6.

Table 5.6 - Past and projected vehicle population

Vehicle Class	2010	2020	2025	2030	2035
Motorcycle, Tricycle and quadracycle	5,593	7,347	8,381	9,415	10,449
Light passenger motor vehicles	108,467	168,224	193,197	218,171	243,144
Heavy passenger motor vehicles	3,452	4,640	5,274	5,908	6,542
Light load vehicles	110,300	167,436	193,325	219,215	245,104
Heavy load vehicles (not equipped to draw)	9,748	11,284	12,119	12,954	13,789
Heavy load vehicles (equipped to draw)	6,879	12,643	15,217	17,791	20,365
Special vehicles	4,982	8,272	9,379	10,487	11,594
Total	**249,421**	**3798,46**	**436,893**	**493,940**	**550,987**

Between 2010 and 2025, the vehicle population is expected to increase by 75%. This increase will be of the order of 98% in 2030 and 121% in 2035 compared to the base year (2010) when the vehicle population stood at 249,421 vehicles. The fleet of light passenger vehicles and light load vehicles will constitute 88% of the total number of registered vehicles based on the projections. Improvements in vehicle technology and fuel consumption have to a certain extent been considered to reflect future progress in vehicle construction and use.

Based on the above assumptions, it is projected that fuel consumption in the road transport sector under the BAU scenario will increase more rapidly for diesel as opposed to gasoline as the ratio of vehicles running on these fuels changes in the future. Thus, based on the year 2010, gasoline is projected to increase by 18% in 2025, a further 7% in 2030 and another 5% by 2035. Diesel consumption is expected to shoot up in 2025 by 165% of the amount used in 2010, 209% in 2030 and 255% by 2035 as depicted in Table 5.7. The evolution of gasoline and diesel used for the period 2000 to 2050 is given in Figure 5.8.

Table 5.7 - Projected Fuel Consumption (tons) for the BAU scenario

	2010	2025	2030	2035
Gasoline	333,283	392,889	410,347	427,948
Diesel	361,616	644,233	1,117,076	1,283,859
% increase gasoline over 2010		16	23	28
% increase diesel over 2010		165	209	255

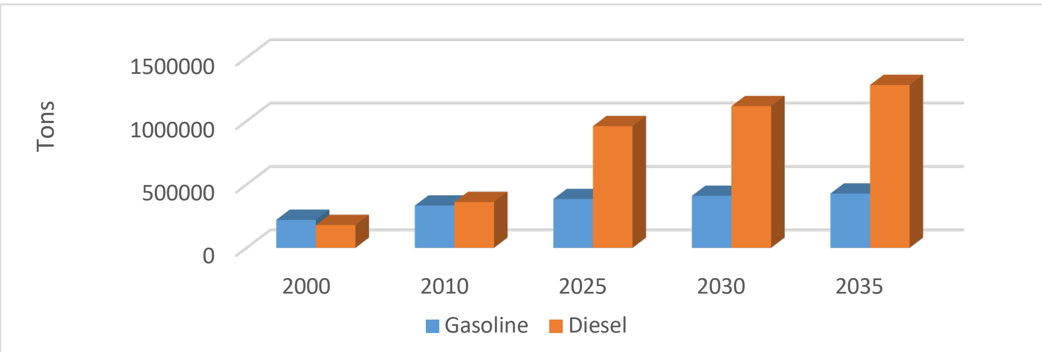


Figure 5.8 - Past and future use of gasoline and diesel for road transportation

In the absence of any mitigation action, this amount of fuel burnt in the road transport sector will contribute a substantial share of national emissions. This consumption trend represented aggregate emissions of 2,223 Gg CO2-eq in the base year 2010 and projected to increase to 4,322 Gg CO2-eq in 2025, 4,912 Gg CO2-eq in 2030 and 5,508 Gg CO2-eq in 2035 respectively. These will represent increases of the order of 94%, 121% and 148% for these three time steps over emissions of the base year 2010. The road transport sector emissions will represent 44% of national emissions of the energy sector in 2025, 43% in 2030 and 42% in 2035.

Aggregated emissions for the BAU scenario for CO_2 and NOx, equated with N_2O, from the SUTMP project is forecasted at 480 Gg CO_2 eq in 2035. These latter figures are retained for calculating the emissions reduction under the mitigation scenario.

5.6.6.3. Mitigation Options

Previous reports (Energy Policy Scenarios for Namibia 2007-2050) on energy needs in Namibia confirmed that due to its greater flexibility, road transport will continue to influence the socio-economic development of the country. However, given the more recent changes and commitments of Namibia within the international context relative to the COP decisions and the SDGs, there is need to review this policy.

Given this new context, the Ministry of Works and City Council of Windhoek embarked on a project to review the road transportation system within the larger framework of Windhoek's green development inclusive of a sustainable transport system for the city and the surrounding areas. Ministry of Works and City Council of Windhoek commissioned the development of a master plan with the support of GIZ. The master plan is intended to provide for an efficient, affordable, equitable, safe and convenient public and non-motorised transport (NMT) for residents of the city and its surroundings. This includes improved linkages towards Okahandja in the north, Rehoboth in the south, and the Hosea Kutako International Airport to the east. The study, Sustainable Urban Transport Master Plan – (SUTMP) - (www.sutp.org) was completed in 2013 and has been partially implemented to date.

In the NC3, a series of mitigation measures were identified and assessed for their mitigation potential. They were

- Fuel switching from petrol to LPG;
- Use of biodiesel by mixing 5% crop-oil to diesel;
- Use of ethanol as E85;
- Use of bio ethanol from woody biomass;
- Improving vehicle fuel use efficiency;
- Management of demand by pooling and bulk loading;

Additional no cost measures that can easily be implemented include

- New legislations to limit speed;
- New taxation policies on import duties and licenses.

5.6.6.4. Choice of Mitigation Options

From this list of potential mitigation measures, only the most prominent ones that were deemed most applicable were further analyzed.

These options were identified as those with the highest payoffs and were assessed for their mitigation potential. These are:

- The introduction of new generation diesel or CNG propelled buses having EURO 3 or 4 emission standards with the objective of reducing the demand for light passenger vehicles by at least 30%;
- Conversion of 25% light load vehicles and light passenger vehicles into dual fuel vehicles using LPG and gasoline; and
- Encouraging pooling and bulk loading in internal transport of goods with incentives to increase registration of ≤15 tons GVM goods vehicles by up to 30% in 2035, thus causing a reduction in the forecast fleet of light load vehicles.

Out of these measures, the first option has been implemented within the framework of the SUTMP, the second one has not taken off due difficulties in developing a reliable supply system while the third option is difficult to evaluate within this assessment.

The SUTMP is a much wider study, incorporating other issues in addition to road transportation. For example, walking and cycling that are not recognized modes of travel due to lack of proper infrastructure and commuter trains are introduced in the master plan as the latter reviews the infrastructure, urbanization model and the transport network. The SUTMP has as baseline the year 2012 and completion of all phases by 2032. Since implementation has not been as initially planned, the completion year of 2032 has been equated with the year 2035 used for assessment of other mitigation measures. Thus, the emissions reduction estimated in the study for the year 2032 has been adopted for the year 2035 in this assessment to keep pace with the delay in implementation. Since the emissions avoided has been computed and presented only for the completed project in the report, this has been adjusted according to the phase that has been implemented and to be completed by the time steps 2025, 2030 and 2035.

5.6.6.5. Penetration of hybrid cars and electric cars and buses

Since the SUTMP covers only part of the national territory of Namibia and integrates buses running on diesel throughout its full implementation phase, the penetration of hybrid and electric vehicles have been additional measures projected for the buses of the SUTMP project as well as for the remaining part of the country. A penetration of 10, 20 and 30% of electric cars for the time steps 2025, 2030 and 2035 has been retained for the remaining cars by their hybrid counterparts. Similarly, a penetration of 5% and 10% has been projected for electric cars and electric buses for the timesteps 2030 and 2035 to allow for maturation of the technologies and successful adoption.

5.6.6.6. Estimation of mitigation potential

The estimates of mitigation potential for the options in the road transportation sector are provided in Table 5.8. Based on the results presented in Figure 30 of page 41 and adopted in this assessment the SUTMP project will lead to reductions of 43.5, 94.2 and 153.2 Gg CO_2 eq in 2025, 2030 and 2035 respectively. Hybrid cars are projected to contribute between 124.3 to 413.5 Gg CO_2 eq and electric cars and buses some 214.2 to 356.8 Gg CO_2 eq during the period assessed. However, when harvesting wood for mitigation in the Energy sector, this activity will result in emissions for transport of the wood from the forest and grasslands to the site of use. This has been computed and is presented in Table 5.8. Thus, the gross mitigation potential in the road transportation sector is projected at 167.8 Gg CO_2 eq in 2025, 560.0 Gg CO_2 eq in 2030 to reach 923.5 Gg CO_2 eq in 2035. Emissions resulting from transport of wood for mitigation in other sectors range from 2.6 to 3.8 Gg CO_2 eq. The net emissions reduction in the road transportation sector after discounting these emissions will amount to 165.2 Gg CO_2 eq in 2025, 556.7 Gg CO_2 eq in 2030 and 919.7 Gg CO_2 eq in 2035.

Table 5.8 – Emissions reduction of evaluated mitigation measures for Road Transportation

Source	2020	2025	2030	2035
SUTMP	10.9	43.5	94.2	153.2
Hybrid cars	0.0	124.3	252.1	413.8
Electric cars and buses	0.0	0.0	214.2	356.5
Gross emissions mitigated		**167.8**	**560.5**	**923.5**
Emissions from wood transport for mitigation purposes	0.0	-2.6	-3.8	-3.8
Net emissions mitigated	**10.7**	**165.2**	**556.8**	**919.7**

5.6.7. Residential sector

Over and above electricity, fuels burned in the residential category for various purposes are fuelwood, charcoal, LPG, kerosene and paraffin wax. Fuelwood is the most consumed fuel and even if it is not of fossil origin, it results in emissions of CO2 in the Land sector and CH4 and N2O when burned in the Energy sector.

5.6.7.1. BAU scenario

Under the BAU scenario, the fuels used by the population in 2010 have been kept as is for future years to project amounts and calculate emissions. That is the per capita use of each fuel is multiplied by the projected population for the years 2025, 2030 and 2035 to obtain the national amounts used. This national amount is then burned to estimate emissions using the IPCC 2006 software. Emission estimates for the BAU scenario which stood at 126 Gg CO_2 eq in 2010, peaked at 138 Gg CO_2 eq in 2015, and is forecasted to be at 124.2 Gg CO_2 eq in 2025, 114.1 Gg CO_2 eq in 2030 and 117.8 Gg CO_2 eq in 2035. This reduction in emissions in the BAU scenario over time is due to the shift from fuelwood to other cleaner sources of energy such as electricity and LPG as the population migrates from the rural areas to towns.

5.6.7.2. Mitigation options

Based on the national circumstances, observed trends over the past 2 decades and expected changes in the lifestyle of the population stemming from socio-economic progress and urbanization, it has been considered feasible to consider 2 fuels where mitigation have significant potentials. These are paraffin wax and fuelwood, the latter offering a win-win situation in both the energy and land sectors. It is projected that paraffin wax use will decrease but not disappear completely as the poorest segment of the population will still rely on this material in remote rural areas and peripheral urban areas for lighting purposes. So, the intensity of use is capped as from the year 2030. A more or less similar situation occurs with fuelwood but the reduction in intensity of use is still projected to decrease up to the year 2025.

The emissions reductions are presented in Table 5.9. Projected mitigation potentials decrease over time for paraffin wax with the reverse for fuelwood. The potential reduction decreases from 19.2 Gg CO_2 eq in 2025 to nil in 2035 while it increases for fuelwood from 26.0 Gg CO_2 eq in 2025 to 32.6 Gg CO_2 eq in 2035. However, total reductions are projected to decrease from 45.2 Gg CO_2 eq in 2025 to 32.1 Gg CO_2 eq in 2030 followed by a slight increase thereafter to 32.6 Gg CO_2 eq in 2035. This represent reductions of the order of 52.3, 43.8 and 44.2% respectively for the years 2025, 2030 and 2035.

Table 5.9 - Reduction in emissions (Gg CO2-eq) in the Residential sector

Source	2025	2030	2035
Paraffin wax	19.2	2.9	0.0
Fuelwood	26.0	29.2	32.6
Total	**45.2**	**32.1**	**32.6**

5.7 IPPU sector mitigation assessment

Emissions from the IPPU sector originate from the categories depicted in Table 5.10.

Table 5.10 - 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.A.2 – Lime production
2.C Metal Industry	2.C.6 – Zinc Production
2.D Non-Energy Products from Fuels and Solvent	2.D.3 – Solvent Use (7) 2.D.3.a – Wood preservation 2.D.3.b – Paint application 2.D.3.c – Asphalt and bitumen
2.F Product Uses as Substitutes for Ozone Depleting Substances	2.F.1 – Refrigeration and Air Conditioning
2.G Other Product Manufacture and Use	2.G.3 – N_2O from Product Use (Medical Applications 2.G.3.a)
2.H Other	2.H.2 - Food and Beverages Industry 2.H.2.a - Beer manufacturing 2.H.2.a – Breadmaking

Out of the total emissions from this sector, cement production contributed 52.3%, zinc production 22.4% and RAC 17.9 % to sum up to 92.6%. With regards to Zinc, no change is projected in the future because even if available production capacity exists, production regressed over the last few years. Additionally, efforts are being made to have the information on the technology used in the manufacturing plant before investigating mitigation. Hence, only cement production and RAC have been privileged for mitigation action.

5.7.1. BAU scenario

For cement production, an increase of 5% annually has been adopted up to the year 2035 as the production capacity exist and the industry is anticipated to expand. This will lead to emissions of 880 Gg CO_2 eq, 1,037 Gg CO_2 eq and 1,193 Gg CO_2 eq in 2025, 2030 and 2035 respectively.

For RAC, it is assumed that there will be an incremental use of 4% annually for stationary air conditioning and refrigeration up to 2025 and 3% onwards up to 2035. Regarding mobile air-conditioning, the projected number of vehicles adopted for estimating emissions in the road transportation category has been adopted. Based on these assumptions, the emissions are estimated at 158.0 Gg CO_2 eq, 185.7 Gg CO_2 eq and 225.5 Gg CO_2 eq for the time steps 2025, 2030 and 2035 respectively

For estimating emissions under the BAU scenario, Lime and zinc production are assumed to stall throughout the period under assessment as this is the observed trend for the past 5 years. N_2O from product use, medical applications, it is assumed that consumption will increase by 2% based on the trend of use adopted for the GHG inventory compilation.

5.7.2. Mitigation assessment

In the cement industry, the possibility of replacing 10 and 20 % of the clinker entering in the production has been considered. The mitigation potential for 10 and 20% replacement of clinker and the % reductions from the BAU scenario are presented in Table 5.11. Emissions reductions is projected to vary from 17.62 Gg CO_2 eq (2%) to 59.65 Gg CO_2 eq (5%) for the low scenario and from 35.24 Gg CO_2 eq (4%) to 119.31 Gg CO_2 eq (10%) for the high scenario.

Table 5.11 - Emissions reduction (Gg CO2 eq) with (%) for 2025, 2030 and 2035 for cement industry

Year	2025	2030	2035
10%	17.62 (2%)	41.48 (4%)	59.65 (5%)
20%	35.24 (4%)	82.96 (8%)	119.31 (10%)

For RAC, two mitigation options are assessed. They are the recovery of the refrigerant from vehicles and refrigerators when they are retired and the replacement of R34a by the new gas R1234yf in vehicles since the latter action has already been implemented in Europe since 2017. It is assumed that other manufacturers will follow, and that all equipment will use R1234yf which has a GWP of 1 as from the year 2025.

Since recovery of refrigerant from used equipment is a new practice, it is assumed to gain momentum with time. Therefore, 5, 10 and 15% of retiring vehicles and refrigerators are targeted with the recovery of the refrigerant. This action is expected to result in a total emission reduction of the order of 4.3 Gg CO_2 eq in 2025, 11.1 Gg CO_2 eq in 2030 and 19.3 Gg CO_2 eq in 2035 from retired vehicles and refrigerators. Reductions of 4.3, 18.7 and 31.2 Gg CO_2 eq are forecasted when new equipment with R1234yf enters the market as from the year 2025 instead of R134a.

The total emissions avoided in RAC is given in Table 5.12. It amounts to 8.5, 29.9 and 50.5 representing reductions of 5%, 16% and 22% for the year 2025, 2030 and 2035 respectively.

Table 5.12 - Emissions reduction (Gg CO2 eq) with (%) for 2025, 2030 and 2035 for RAC

Year	2025	2030	2035
Stationary air conditioning and refrigeration	4.0	10.7	18.1
Mobile air conditioning	4.5	19.2	32.4
Total (%)	8.5 (5%)	29.9 (16%)	50.5 (22%)

The mitigation assessment based on the assumptions provided is projected to reduce emissions in the IPPU sector by 43.8, 112.8 and 169.8 Gg CO2 eq, representing 4%, 8% and 11% for the year 2025, 2030 and 2035 respectively. The high mitigation option for cement is chosen. This is depicted in Figure 5.9

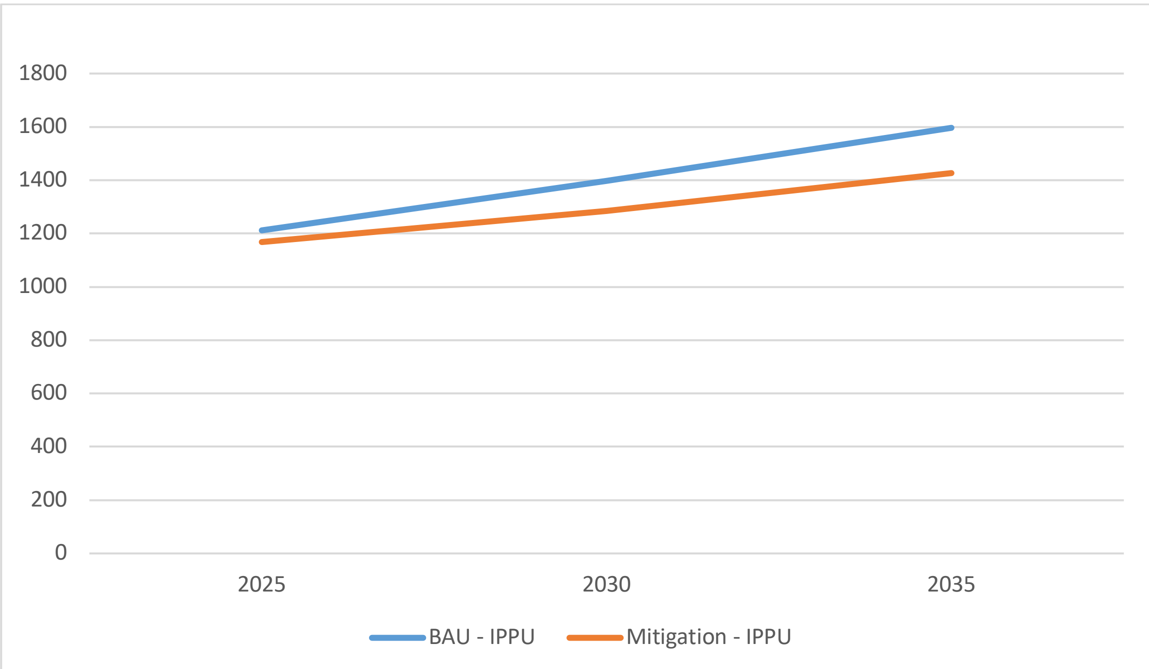


Figure 5.9 - Emissions under BAU and mitigation for the IPPU sector

5.8 AFOLU mitigation assessment

5.8.1. Description of sector

All categories of the AFOLU sector are covered in the inventory of this report and can be referred to for more details. Following the availability of new datasets and background information on the AFOLU sector, the inventory has been recomputed on these latest data and information detailed in the inventory chapter. This updating substantially increased the sink capacity of the sector and brought forward the high potential for sustainable use of the invasive bush that has colonized the vast 53 M hectares of initial grassland which is now classified as Other Wooded Land under Forestland. This invasion seriously affected the carrying capacity of the grasslands/rangelands which in turn impacted negatively on the livestock sector and biodiversity. The government of Namibia has implemented a rangelands rehabilitation programme to make use of the invasive bush sustainably while improving the carrying capacity to its previous potential.

Given this situation, only the LAND subsector is considered for mitigation.

5.8.2. BAU scenario

The AFOLU sector stayed on top of the list of key categories for Namibia during the whole NC4 inventory time series. The sink capacity of the sector gradually increased as a result of the bush invasion over greater areas coupled with accumulation of biomass in the invaded areas. Concurrently, national initiatives to protect forestland and reduce use of biomass also helped in this increase of sink capacity. Net sink capacity of the AFOLU sector increased following the same trend in the LAND subsector. It is clearly seen how the sink capacity at national level increased as provided in Figure 5.100. AFOLU removals were estimated at 107,450 Gg CO_2 eq in 2010 to increase 121,575 Gg in 2015. In net terms at national level, net removals increased from 86,725 Gg CO_2 eq in 2010 to 100,497 Gg CO_2 eq in 2015. On this trend, Namibia's land sector will remain a sink but become CO_2 neutral under the scenario of increased harvest and use of the invader bush.

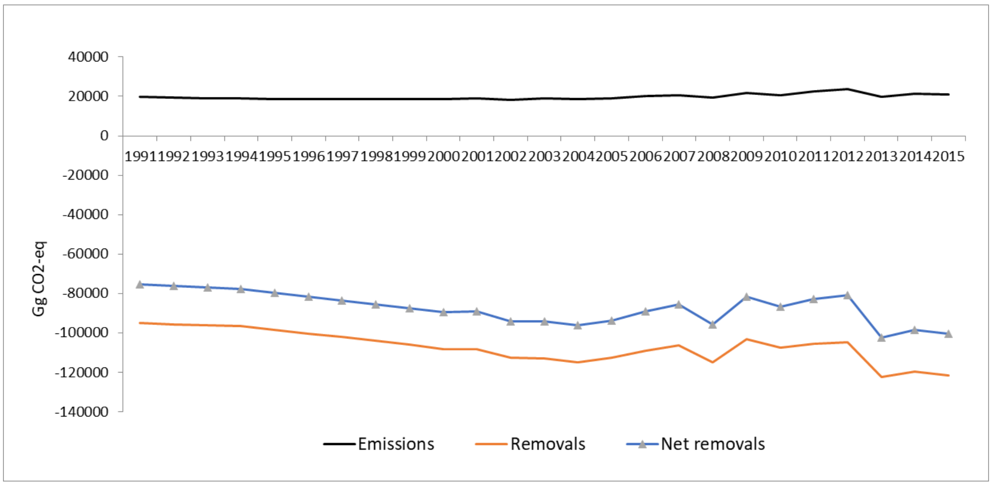


Figure 5.10 - Evolution of national emissions, national removals and the overall (net) situation (Gg CO_2-eq), (1991 – 2015)

The assumptions made when working emissions for the BAU scenario are:

Livestock

- An increase of 3% of livestock population every 5 years for cattle and poultry with the other categories of animal kept stable up to 2035;
- No change was brought to animal husbandry practices relative to feeding situation and manure management practices

Land

- National programmes for the protection of Forest lands is deemed to reduce deforestation to a strict minimum with a loss of 7500 hectares annually to OWL.
- OWL will also stabilize as invasion of grassland in the southern part of the country is estimated to be not occurring due to rainfall being limiting. An area of 2500 ha annually is estimated to be converted to Forestland annually. A loss of 100 ha annually to Settlements has been estimated up to 2035.
- Cropland will reach 350,000 ha by year 2020 and is estimated to stay stable as this area is required for food production.
- With no invasion occurring, the Grassland area of 3.8 M ha will remain same. Exploitation of the invader bush in OWL are not expected to affect this land class as it will be primarily wood removal as opposed to full clearing.
- Settlements area will increase marginally by 100 ha an annual basis from OWL as inclusion from Cropland or Grassland is estimated not to occur.
- The area of Wetlands and Other lands is estimated to remain stable.

Other parameters

- Wood removals for fuelwood and poles will continue to occur and use rate has been kept same in the same trend between 2000 to 2010. Wood removal to produce charcoal and for export of fuelwood will also increase under the BAU scenario.
- The area disturbed due to burning is estimated at 2.5 % of total area of Forest Land, OWL and Grassland.
- Non-CO2 emissions and aggregate sources
    - The amount of fertilizer used has been kept stable as the area of Cropland is not expected to change.
    - The amount of manure for indirect and direct losses from soil was estimated using the IPCC software with the animal population mentioned above.
    - Addition of compost from this mitigation action in the waste sector is not accounted for in this analysis.

Harvested wood product

- The sink capacity for this subcategory was estimated as stable since wood harvested and stored is forecasted to be minimal with practically no change in the estimated for HWP.

5.8.3. Mitigation in the AFOLU sector

Mitigation in the AFOLU sector is considered plausible only in Forestland as the other categories do not offer the guarantee for them to be realised within the national context. The action is directed at the sustainable use of woody biomass, namely invader bush from the OWL land class. Present uses of invader bush consist of:

- Fuelwood
- Charcoal manufacture
- Burning for energy purposes in the manufacturing industry
- Production of pellets from invader bush in the Cheetah environment to protect the latter
- Animal feed
- Structural material for housing and kraals

It is also projected to use significant amounts of invader bush for producing electricity in lieu of imports of this commodity produced from Coal primarily (See Energy sector mitigation).

5.8.3.1. Sustainability of invader bush exploitation

The exercise done to assess sustainability of the exploitation of invader bush is presented in Table 5.13. The area needed for providing the required amount of biomass for the 5 MW plant is 4,000 ha annually. The area earmarked per unit is 108,000 ha. Annual harvest of the regrowth biomass of the harvested areas over a period of 20 years will be met by a potential area of 80,000 ha. Thus, there is ample acreage available for the electricity generation unit to work with biomass as feedstock on a sustainable basis over its lifetime (20 years) since the area earmarked (108,000 ha) for each plant exceeds the potential area required (80,000 ha).

Table 5.13 - Sustainability of invader bush exploitation (ha) for a 5 MW electricity generation plant

Area earmarked for de-bushing	108,000
Annual area de-bushed for electricity production	4,000
Area needed for sustainability of system over 20 years	80,000

5.8.4. Options for mitigation in LAND sector

Numerous options exist for mitigation within the LAND sector but only those having a potential to be successfully implemented and closely associated with the national circumstances have been assessed. These options are:

- Sustainable/reduction in removal of poles for construction of dwellings and kraals;
- Sustainable removal of invader bush for various purposes; and
- Reducing deforestation.

<u>Sustainable/reduction in removal of poles</u>

The use of poles has been regressing over time due to the shift from wood to other construction materials such as bricks and corrugated iron sheets. Additionally, timber for construction purposes are also being imported and poles can also come from some species of the invader bush whence its harvest is required in the process of rehabilitation of rangelands. Removal of poles and timber is also expected to decrease with declining rural population. These actions are expected to lead to a decrease of about 60% in 2025, 70% in 2030 and 75% in 2035 of the number of poles under the BAU scenario. Estimates of future removals and emissions avoided of poles are given in Table 5.14. Emissions avoided are projected to be 920.3 Gg CO_2-eq in 2025, 1,012.0 Gg CO_2-eq in 2030 and 994.0 Gg CO_2-eq in 2035. These reductions represent 60%, 70% and 75% of BAU.

Table 5.14 - Estimates of poles removals from forests

Year	Estimated timber and poles (m3) removals (BAU)	Emissions from removals (Gg CO_{2-eq})	Emissions with mitigation (Gg CO_{2-eq})
2025	319,563	1,533.8	613.5
2030	301,197	1,445.5	433.7
2035	276,104	1,325.3	331.2

<u>Sustainable harvest of invader bush for various purposes</u>

As described above, the sustainable removal of invader bush to rehabilitate rangelands is a promising mitigation option which also provides for adaptation and preservation of biodiversity. Projected removals of invader bush under the BAU and mitigation scenario, and the extent of emissions avoided are given in

Table 5.15. Projected reduction in emissions is -569.3 Gg CO_2-eq in 2025, 1,945.4 Gg CO_2-eq in 2030 and 7,440.6 Gg CO_2-eq in 2025 representing -6%, 16% and 42% for the same years respectively. It is to be noted that the start of power plants using biomass in 2025 offsets the reductions of other measures and shows a slight increase of emissions over the BAU.

Table 5.15 - Invader bush harvested (t) under BAU and mitigation and emissions avoided (Gg CO_2-eq)

Year	BAU	Mitigation	Emissions avoided
2025	1,873,485	1,992,090	-948.8
2030	2,591,386	2,186,078	3,242.3
2035	3,713,265	2,163,093	12,400.9

BAU emissions and te amounts avoided from the mitigation actions reduction in poles harvest and wood removals are given in Table 5.16. Emissions under the BAU scenario increased from 23,735 Gg CO_2-eq in 2025 to 38,345 Gg CO_2-eq in 2035, an increase of 62%. From no mitigation in 2025 with emissions being still at 28.5 Gg CO_2-eq, the reduction jumped to 13,394.9 Gg CO_2-eq in 2035. The combined level of mitigation from the two actions evolves from nil in 2025 to 35% in 2035 for the AFOLU sector.

Table 5.16. BAU emissions, and projected mitigation potential (Gg CO2-eq) with (%) reduction

	2025	2030	2035
BAU AFOLU	23,735	29,333	38,345
Reduction poles	920.3	1012	994
Reduction Wood removals	-948.8	3,242.3	12,400.9
Total reduction (%)	-28.5 (0%)	4,254.3 (15%)	13,394.9 (35%)

5.9 Waste mitigation assessment

5.9.1. Description of sector

In Namibia, urbanized areas have collection and separation systems for the management of MSW and industrial waste. Materials such as metal, plastic and paper are removed and recycled in regions like Windhoek and Walvis Bay. Sand and inert building wastes are removed, and the remainder is sent to landfills. Industrial waste and sewage sludge are also landfilled on the same sites either in separate cells or along with MSW. Sewers are present in high urban areas while septic tanks are used in houses of low urban areas. Industrial liquid waste is generated during fish processing and in abattoirs. Sludge from domestic wastewater management systems is sent to landfills. Most solid waste generated in rural areas are open burned.

Business As Usual Scenario

Urban dwellers produce a higher amount of waste while the poorer rural population have a lower waste generation rate. Figure 5.11 shows the average waste produced per capita (t/yr) and the evolution in population in urban high, urban low and rural areas.

Under the BAU scenario, all solid waste from the high and low urban areas are landfilled while in rural areas, the solid waste is open burned. The projected amount of solid waste has been estimated as per the rate of generated per capita and the projected population of the high urban, low urban and rural areas. This data is then fed in the IPCC 2006 software to estimate the resulting emissions.

Emissions are projected to be 232.3, 281.2 and 340.0 in 2025, 2030 and 2035.

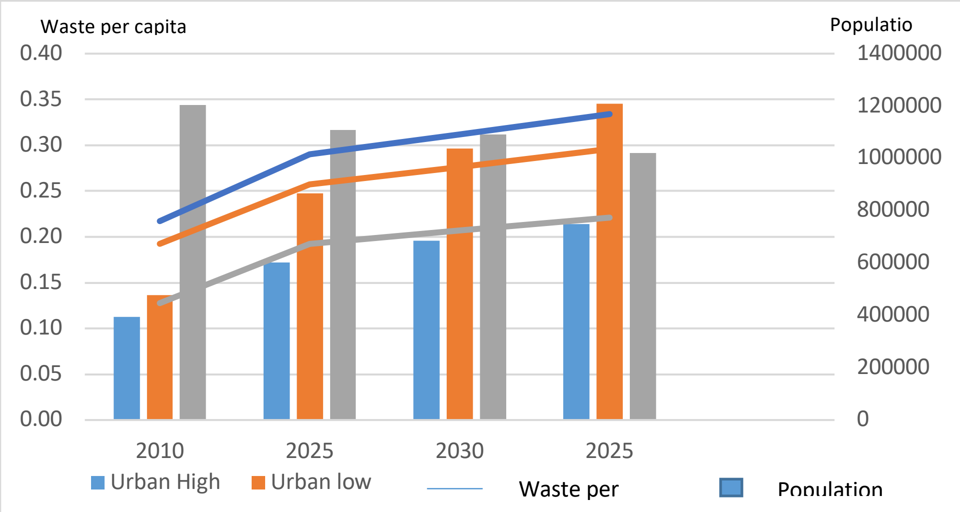


Figure 5.11 - Waste generation for 2025, 2030 and 2035

Since Namibia has an extensive territory, transporting waste over long distances is not a sustainable option. Potential MSW from the urban high regions of Walvis Bay, Swakopmund and Windhoek represent the major portion of waste generated in the country and is thus, the primary source of input for mitigation purposes. The projected amount of MSW for these three regions is given in Table 5..

Table 5.17 - Forecasted amount of MSW from urban high regions

Year	Amount of MSW (t)
2025	174,656
2030	212,362
2035	250,230

5.9.2. Mitigation options

The change in lifestyle and growth of the urban population will result in an increase of the amount of waste to be managed every year. Burning and uncontrolled landfilling are not considered sustainable options as they lead to GHG emissions. It is therefore important to assess the potential of managing the waste differently and at the same time mitigate GHG emissions if current practices are changed. Emissions from domestic and industrial waste-water are minimal and have not been considered for mitigation.

There are numerous options for the valorisation of waste as a source of energy or raw material such as compost, while metals and plastic are recycled. These include:

- Recycling of plastic and metallic components after segregation;
- Composting through various fermentation pathways;
- Waste to energy projects via various channels and technologies;
- Production of biogas.

Systems coupling two or all four above options can be adopted for a holistic management of MSW and enabling the best management practice.

5.9.3. Choice of Mitigation Option

Out of the various options presented above, and taking into consideration the existing system for management of waste, the most attractive option in the short term and medium term appears to be the mix flaring and conversion of landfill gas (LFG) to electricity in high urban areas where most of the solid waste is generated coupled with segregation and composting in low urban and rural areas. Further work is warranted to assess other options to better deal with waste in the longer term as well as the latest technologies for converting waste to energy such as pyrolysis.

Collection and conversion of LFG to electricity/flaring

The landfills were developed in the 1980s such that LFG production is ongoing at varying rates across them. Even if the landfills have not been designed specifically with well-controlled cells for recovery and conversion of methane to electricity, it is still possible to embark on this path via the commissioning of a collection system for so-called cells (areas) where the decomposition is mature enough to produce LFG of quality for conversion. Because of these drawbacks, it is assumed that only 80% of the methane produced will be captured and either flared or converted to electricity. The potential for reduction of emissions through conversion to electricity/flaring is projected at 50.8 Gg CO_2-eq in 2025, 63.3 Gg CO_2-eq in 2030 and 77.7 CO_2-eq in 2035.

Composting

In the low urban and rural areas, the generated rate of MSW limits the choice of options for mitigation. The most appropriate one within the national context is to produce composts for use in cropping from the organic component of the waste. While in the low urban areas, there may be a need for segregation at source and thereafter at the dump site or landfill, this practice can be avoided as most of the solid waste in rural areas are of organic origin. It is expected that 80% of the solid waste generated in both the low urban and rural areas can be recovered for composting. A gradual adoption rate of this practice is estimated for rural region with 25 % of waste composted in 2025, 50% in 2030 and 75% in 2035.This will result in an emission reduction of 72.3 Gg CO_2-eq, 101.0 Gg CO_2-eq and 135.1 Gg CO_2-eq in 2025, 2030 and 2035.

Table 5.18 - Emissions reduction from composting of solid waste in low urban and rural areas (Gg CO2-eq)

Year	2025	2030	2035
Low urban area	64.7	85.4	111.0
Rural area	7.6	15.6	24.1
Total	72.3	101.0	135.1

When cumulating all mitigation options for solid waste, the emissions reduction will reach 123.1 Gg CO_2-eq in 2025, 164.3 Gg CO_2-eq in 2030 and 212.8 Gg CO_2-eq in 2035. These reductions represent 53%, 58% and 63% of the BAU emissions and can be depicted from Figure 5.12.

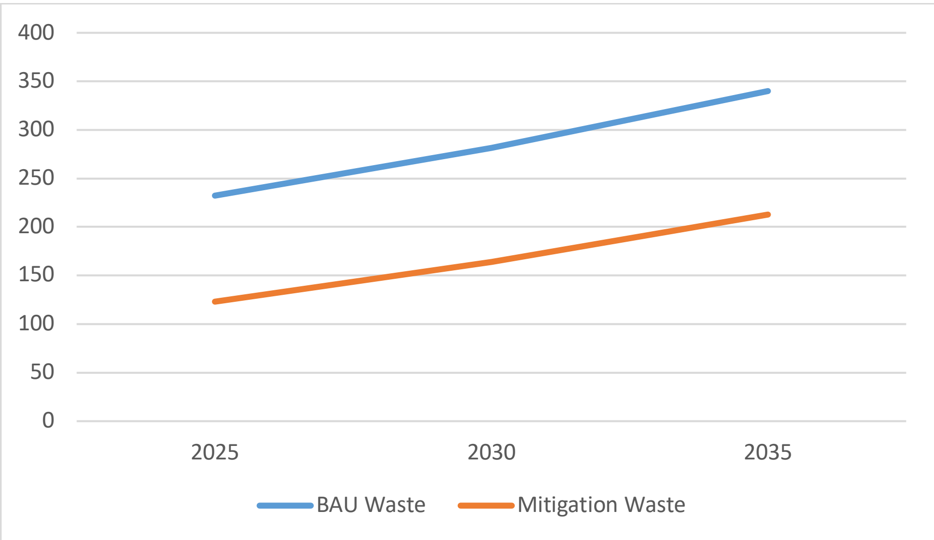


Figure 5.12 - Emissions for BAU and mitigation actions for solid waste (Gg CO2-eq)

6. Other information considered relevant to the achievement of the objective of the Convention

6.1 Transfer of Technologies

Namibia pays particular attention to the transfer of technologies and provided for it in the CCSAP under the item *"Promote and support development of technologies for mitigation and adaptation"*. The transfer of, and access to, environmentally sound technologies and know-how, the development and enhancement of endogenous capacities, technologies and know-how, and measures relating to enhancing the enabling environment for development and transfer of technologies are critical to the achievement of both adaptation and mitigation to achieve the objective of the Convention.

Given the lack of funds and capacities, Namibia has not yet completed an exhaustive assessment of its technology needs and transfer. The partial ad-hoc assessments continued within the framework of the preparation of the NC4, particularly for measures and actions projected for adaptation to and mitigation of climate change. This delay in the completion of a full technology needs assessment is impeding on the readiness of the environment for the development and implementation of adaptation and mitigation projects. As well, this situation impeded on the needs assessment for capacity building and training resulting in a lack of national capacity for supporting project implementation.

Some transfer of technologies took place concurrently with the implementation of mitigation and adaptation projects. In line with the updating of the mitigation and adaptation needs for more ambitious programmes for the transition to a low carbon economy and building resilience within a shorter timeframe, there still exist a big gap to fill to achieve readiness for implementation of the steps planned for implementing the Convention.

A list of the most urgent needs related to technology, soft and hard, assessment and transfer for mitigation is provided below:

- In-depth Technology Needs Assessments for mitigation
- Exploitation, extraction and transport of natural gas for inland use (Kudu project)
- Electricity generation from natural gas (CCGT)
- Wind power harnessing and electricity generation
- Geothermal energy
- Concentrated Solar Power for electricity production
- Photovoltaics for generating electricity for the grid
- Off grid PV electricity generation for rural electrification
- Technologies for conversion of biomass to electricity
- Photovoltaic pumps
- Latest technologies for rail and road transport
- Low emissions sustainable urbanization
- Solid and liquid waste treatment systems
- Waste to electricity
- Low emissions agricultural systems

Regarding adaptation, the need also arises for the transfer of a multitude of technologies for various economic sectors. The ones necessitating most urgent action to safeguard livelihood and welfare of the poorer most vulnerable segment of the population are agriculture and water resources.

The prioritized technologies for agriculture are irrigation and water harvesting, conservation agriculture, crop diversification, use of improved indigenous crop germplasm, use of well adapted indigenous livestock breeds, increased seed and fertilizer (incorporating organic fertilizers) availability, shared water resource management, early warning systems, drought mitigation measures, restoration of rangelands and improved livestock management policies and strategies.

Adaptation in the water resources sector will include increasing reservoir capacity, improve soil conservation, water recycling for reuse, increase water use efficiency, harvesting rainwater, use drought tolerant crops and desalination amongst others.

6.2 Research and systematic observation

Though the scientific evidence indicates that climate has changed significantly over and above that caused by natural variability due to man-made (anthropogenic) interference in the climate system, (IPCC, 2014) climate change and its impacts are still not well understood by major components of the population of developing countries. There exists the need to undertake research to quantify the potential impacts at the local, national and regional levels to enable the proper development of practical solutions for adaptation and mitigation.

Namibia as a developing country nation is limited in capacity for in-depth climate research but can still contribute to the international agenda through collaboration with the bilateral and multilateral institutions to move the scientific knowledge forward. On the other hand, Namibia must invest in systematic observation and research to better understand its vulnerability to climate change and eventually develop and implement fool proof adaptation actions to cope with the impacts of climate change on its socio-economic sectors. Concurrently, Namibia must provide the most accurate information on its emissions and sinks in the national GHG inventory. To achieve this, the country must collect data/make systematic observations and undertake research to develop country specific emission factors for use in the compilation of its GHG inventory. The strategy aims at the following:

- Collect data, model climate change and generate scenarios at national, regional & local levels
- Monitor ecosystem and biodiversity changes and their impacts
- Conduct climate-proofing research
- Make observations on sea level rise for improved planning
- Establish a centre for research and training on climate change
- Conduct inventories on traditional / indigenous knowledge and coping practices
- Undertake studies on the cost of adaptation and mitigation
- Study macroeconomic and sectoral impacts of climate change
- Collect data and information required to develop country-specific emission factors

6.3 Education, Training and Public awareness

To effectively address climate change adaptation and mitigation, it is essential that the managers of responsible and leading institutions, the wider stakeholder groups, the private sector and the targeted segments of the population are sufficiently educated, trained and aware of what is expected from them. Climate change is factual and so important nowadays that addressing it does not rest on Government and authorities only but on the population at large. Thus, all have to be properly educated on its cause and effects to enable them to make their contribution at their respective levels. Thus, education has to be formal and informal. Presently, climate change is only part of the tertiary curriculum as modules of some disciplines. The intent is to gradually include climate change as a component of the primary and secondary curricula and extend it in the tertiary curriculum to prepare the coming generations to adapt and mitigate. Concurrently, climate change will be introduced in the vocational training programmes and informal education will be resorted to with the support of NGOs and CSOs, the objective being to inculcate the basic knowledge on climate change to the adults out of the educational system.

It is recognized that a significant portion of the population lacks awareness on climate change issues they are exposed to notwithstanding their role in mitigation. This is due to lack of resources and a limited number of national experts to effectively deliver on this issue. It is planned to enhance public awareness programmes to maximize outreach, the final objective being to cover all segments of the population countrywide. This is deemed essential as the public needs to have access to the latest information to integrate them in the process and enable them to successfully participate in actions to be implemented. The strategy for raising public awareness to the required level will be achieved through the following actions:

- Awareness raising and public education on climate change
- Promote and facilitate development of public awareness materials on climate change
- Facilitate access of climate change information to the public
- Promote public participation in addressing climate change and development of adequate responses

6.4 Capacity Building

Namibia has built some capacity for reporting to the Convention and on its implementation. However, with the changes in the standard of reporting, the transparency framework and the urgency of implementing the NDC, there still exist a large gap to fill. Much hope rests on the Capacity Building Initiative for Transparency (CBIT) project which is under preparation for approval by the GEF to make up for this lack of capacity. Technical capacity building concerns mainly mitigation and adaptation technologies earmarked in the respective chapters for the measures that are most prominent and prioritized in this communication and other reports submitted to-date. Capacity building also concerns overarching issues. As a developing country, Namibia needs robust institutional structures to take on and implement programmes and activities on climate change. Building human and institutional capacity to address climate change will be a fundamental component of the Namibian strategy on climate change. Capacity building for climate change will thus include further development and strengthening of personal skills, expertise of national experts and of relevant institutions and organizations on adaptation, mitigation and reporting. Capacity building will involve a wide group of stakeholders, including the government, NGOs, research institutions, local communities and the private sector.

Some of the areas identified for further capacity building are:

- Mainstreaming climate change in national, local and sector policies, development plans & programmes
- Strengthen institutional capacity for the management of climate change projects
- Integration of climate change in the cultural behaviour of the population
- Develop and implement educational programmes on climate change and its impacts
- Promote and facilitate development of educational materials on climate change
- Facilitate and support training of scientific, technical and managerial personnel in climate change
- Develop disaster risk reduction capacity building plans and programmes for climate change
- Establish a Climate Change Resource Centre and Climate Change database
- Develop a GHG inventory management system
- Develop and implement MRV systems for tracking and reporting on mitigation and adaptation projects
- Evaluation of emissions reductions of mitigation projects

6.5 Information and networking

Climate change is a global problem requiring the cooperation of all to tackle it successfully. Namibia as a Party to the Multilateral Environmental Agreements and various other Protocols and Agencies aims to preserve the environment within the sustainable development Agenda. This is in line the Convention. To attain this objective, Namibia has identified the following actions on the international and national fronts.

- Strengthen and enhance international collaboration, linkages and networking among stakeholders involved on the environment and climate change related issues
- Participate in regional and international cooperation programmes and activities on climate change
- Promote international North-South and South-South collaborative research that will facilitate generation of climate change adaptation and mitigation evidence-based information
- Facilitate achievement of UN environment international obligations under various Conventions, especially UNFCCC and the Sustainable Development Goals
- Organize a platform for sharing information and results on the implementation of the Convention at the national level to further inform and raise awareness of stakeholders at large of achievements
- Create a national database on climate change for use by scientists, government, the private sector and students

7. Constraints and Gaps, and related Financial, Technical and Capacity Needs

7.1 Reporting

Preparation of the INC and SNC was on an *ad-hoc* basis and did not require a permanent set-up that would have proven too onerous for the country being given the scarcity of resources. Thus, reporting on the different thematic areas was outsourced and the CCU of MET catered for the whole process. The enhancement of the reporting requirements demands for higher standards and a permanent framework to enable the sustainable production of these reports while guaranteeing their quality. In addition, there is a need to develop and establish permanent systems for monitoring, reporting and verifying mitigation actions (MRV) and other activities related to the Convention.

During the exercise of strengthening of the existing institutional arrangements, numerous and very daunting challenges cropped up. The most urgent ones were:

- Insufficient capacity of the coordinating body as well as lack of institutional and technical skills within the different thematic areas of the NC;
- To maintain a motivated permanent coordinating body and/or personnel;
- Staff scarcity / unavailability in collaborating institutions due to their already overloaded schedules and staff turn-over; and
- Lack of incentives and adequate funds to develop and maintain the system in place.

The national experts in the various departments will need capacity building for implementation, follow-up, quality control and reporting. New recruits to perform independent validation and verification will have to be trained. Unless technical assistance is provided, the country will have to look for alternatives, such as outsourcing resource persons to provide for these capacity building needs.

Financial resources are also lacking to develop and implement the framework for sustainable reporting and the MRV system. Already, government budget is strained due to the numerous national priorities and it may prove difficult to allocate enough funds to cover all these expenses. It is hoped that funds will be made available through the multilateral organizations like the Global Environment Facility to support activities, including the very urgent capacity building needs, to enable Namibia develop, establish and implement this framework.

7.2 GHG inventory

Namibia, as a developing country, has its constraints and gaps that need to be addressed to produce better quality reports for reporting to the Convention. The following problems were encountered during the preparation of the national inventory of GHG emissions:

- Information required for the inventory had to be obtained from various sources as no centralized archiving system has been developed for GHG inventory preparation;
- Almost all of the AD were not in the required format for feeding in the software to make the emission estimates;
- End-use consumption data for all the sectors and categories were not always readily available;
- Reliable biomass data such as timber, fuelwood, wood waste and charcoal consumed or produced were not readily available and were estimated;
- Inconsistencies were found when data were collected from different sources;
- Solid waste characterization data, amount generated and wastewater generated are not regularly measured and had to be derived;

- EFs have to be derived to better represent national circumstances and improve estimates;
- National experts need more training on the GHG estimation software to become fully conversant with them.

7.3 Mitigation and Adaptation

Implementation of mitigation and adaptation measures and actions is a major challenge for the country in view of the multiple constraints and gaps that exist in various areas, namely at the institutional, organizational and individual levels. There is a need to create the enabling environment in the country. Needs also exist for improving the technological assessment and transfer for mitigation and the technical capacity of national experts. Further assessments still have to be undertaken to identify more prominent measures and actions as well the prioritize those with the highest potential for successful implementation.

Barriers will have to be removed to speed up the process of implementation of mitigation and adaptation, and the preparation of project proposals for funding.

The appropriate funding amounts and timing are important features to take into consideration when these measures and actions, especially the implementation aspect, are aligned with the country's development strategy and agenda. Implementation is even more difficult as a result of the significant amounts of sustained funding required to develop and implement mitigation and adaptation projects. Up to now, Namibia has not tapped much funding to support its mitigation strategy. There is need for these shortcomings to be corrected by the international community through further consolidation of the Green Climate Fund for the latter to fully fulfill its role. It is also expected that new instruments will be developed to assist Non Annex I Parties to play their role in implementing the Convention urgently because of their higher exposure and vulnerability to the impacts of climate change. A list of actions requiring funding have been provided in the BUR1. An estimate of funds needed has also been provided in the INDC for the most urgent actions for both mitigation and adaptation to the 2030 time horizon.

7.4 Capacity Building and Financial Needs

Namibia's needs to implement the Convention relates to financial, technical, and capacity building primarily. Technical capacity building concerns mainly mitigation and adaptation technologies earmarked in the respective chapters for the measures that are most prominent and prioritized in this communication and other reports submitted to-date. Several other overarching issues have to be also addressed for successful implementation of the Convention in addition to capacity building of these cross-cutting issues.

As a developing country, Namibia needs robust institutional structures to take on and implement programs and activities on climate change. Building human and institutional capacity to address climate change will be a fundamental component of the Namibian CCSAP. Capacity building for climate change will thus include further development and strengthening of personal skills, expertise and of relevant institutions and organizations on adaptation, mitigation and reporting. Capacity building will involve a wide group of stakeholders, including the government, NGOs, research institutions, local communities and international organizations.

Some of the actions identified in the CCSAP are:

- Strengthen human resource capacity building for climate change
- Main-stream climate change in national, local and sector policies, development plans & program
- Strengthen institutional capacity for climate change management
- Mainstream climate change in the media
- Develop and implement educational program on climate change and its impacts
- Promote and facilitate development of educational materials on climate change

- Facilitate and support training of scientific, technical and managerial personnel in climate change
- Develop disaster risk reduction capacity building plans and programmes for climate change.
- Establish Climate Change Resource Centre and Climate Change database

Avenues concerning funding have been identified in the NCCP and further detailed in the NCCSAP. The NCCP highlighted that government consider and explore a range of multi- and bilateral funding options including grants, concessional and non-concessional loans, as well as market-based instruments. The NCCP also emphasises the importance of evidence-based strategies and action plans, and observes that "Climate change research needs to be properly coordinated, and its benefits optimised to meet the needs of decision-makers in Namibia". The NCCSAP on the other hand identified the need to maximise government financing instruments at the national and local levels; leverage private sector investment; and access scaled-up, new and additional (external) financial resources. The need also exists to develop assessment tools to inform decision-making, and to establish partnerships among national and local government agencies, business, professional and other private groups, community-based organisations, academic and scientific organisations and civil society organisations in order to realise its objectives. Policy and incentive mechanisms must be introduced to facilitate and leverage private sector investment in climate change, and it is expected that Public Private Partnerships will contribute both monetary and human resource capacity to implement the required actions.

8. References

Archer, S.R., Davies, K.W., Fulbright, T.E., McDaniel, K.V., Wilcox, B.P. and Predick, K.I., 2011, Bush Management as a Rangeland Conservation Strategy: A Critical Evaluation, in D.D. Briske (ed.), Conservation Benefits of Rangeland Practices: Assessment, Recommendations, and Knowledge Gaps, United States Dept. Agriculture, Natural Resources Conservation Service

Barnes JI, Nhuleipo O, Muteyauli PI and MacGregor, J, 2005. Preliminary economic asset and flow accounts for forest resources in Namibia

Barnett et. Al. 2008. Jon Barnett, Simon Lambert & Ian Fry (2008) The Hazards of Indicators: Insights from the Environmental Vulnerability Index, Annals of the Association of American Geographers, 98:1, 102-119. February 2008.

BoN 2018. Bank of Namibia Annual Report 2018. Bank of Namibia. March 2019

Crawford and Tretorn, 2016. Adaptation Status Quo

De Klerk, J.N., 2004, Bush Encroachment in Namibia, Report on Phase 1 of the Bush Encroachment, Monitoring and Management Project, Ministry of environment and Tourism, John Meinert Printers, Windhoek

Dieckman U and Muduva T., 2010. Charcoal production, Practices and implications.

Colin, Christian and Associates, 2010, The Effect of Bush Encroachment on Groundwater Resources in Namibia: A Desk Top Study, Namibia Agriculture Union, Windhoek, Namibia.

Dirkx, E. Hager, C., Tadross, M., Bethune, S. and Curtis, B. 2008. Climate change vulnerability and Adaptation Assessment. Developed by Desert Research Foundation (DRFN) and Climate Systems Analysis Group, University of Cape Town for the Ministry of Environment and Tourism.

Elliott, C. 2012, Prefeasibility Study for Biomass Power Plant, Namibia. Biomass Supply Chain Assessment, WSP Environment & Energy South Africa, Bryanston, South Africa

Eriksen and Kelly (2006). Eriksen, S.H. and Kelly, P.M. 2006 Developing Credible Vulnerability Indicators for Climate Adaptation Policy Assessment. Mitigation and Adaptation Strategies for Global Change, 12, 495-524. Springer Link May 2008

FAO. (2018, November 07). *Food and Agricultural Organization (FAO) of the United Nations (UN): Namibia Water Report 29, 2005.* Retrieved from AQUASTAT: http://www.fao.org/nr/water/aquastat/countries_regions/NAM/

Feller S., Mahony J., Sasanowich R., and Wise J. 2006. Development of the Bushblock industry in Namibia

Food and Agriculture Organization of the United Nations (FAO), 2014, Country profiles: Namibia. Available at http://faostat.fao.org/site/666/default.aspx

Food and Agriculture Organization of the United Nations (FAO), 2010, Global Forest Resources Assessment 2010.

Fussel 2009. Hans-Martin Fussel. Review and quantitative analysis of indices of climate change exposure, adaptive capacity, sensitivity, and impacts. Background note to the World Development Report 2010. August 2009

Füssel, H.M. and Klein, R.J. 2006. Climate change vulnerability assessments: An evolution of conceptual thinking. Climate Change, 75, 301-329. http://dx.doi.org/10.1007/s10584-006-0329-3

Fussel, HM. 2009. Development and Climate Change. Background note to the World Development Report.

GDP Inflation/Economic indicator of countries 2014. Namibia Annual GDP and GDP growth rate/forecast (1980-2015). http://www.gdpinflation.com/2014/08/namibia-aanual-gdp-and- gdp-growth-rate.html

GIZ 2015. Jokisch, Alexander. 2015. Rainwater harvesting in Namibia on household level. 10.13140/RG.2.1.3320.0081

Government of Namibia. July 2002. Initial National Communication to the United Nations framework convention on climate change. Windhoek: Ministry of Environment and Tourism.

Government of the Republic of Namibia (GRN), 2004, Namibia Vision 2030: Policy framework for long-term national development, Windhoek.

Guillaumont, P. (2015). Measuring Vulnerability to Climate Change For Allocating Funds to Adaptation, in Barrett B., Carraro C., De Melo J. (dir.) Towards a Workable and Effective Climate regine, Economica. 515-533

Hager, C., Schultz, R. and Von Oertzen, 2007, Turning Namibian Invader Bush into Electricity: The CBEND Project, 12th Congress of the Agricultural Scientific Society of Namibia, Neudam, Namibia.

Hinkel, J., 2011. 'Indicators of vulnerability and adaptive capacity: towards a clarification of the science policy interface', Global Environmental Change, Volume 21, pp. 198–208

Humavindu, M.N. and Stage, J., 2013, Key Sectors of the Namibian Economy, Journal of Economic Structures, 2, 1-15

IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.

IPCC, 1996. *Revised 1996 IPCC Guidelines.*

IPCC, 2003. Good Practice Guidance for Land Use, Land Use Change and Forestry.

IPCC. (2014). Intergovernmental Panel on Climate Change (IPCC): Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. In C. B. Field, V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, . . . L. L. White, *Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (p. 1132). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press

Klein, Richard. (2009). Identifying Countries that are Particularly Vulnerable to the Adverse Effects of Climate Change: An Academic or a Political Challenge? Carbon & Climate Law Review. 3. 284-291. 10.21552/CCLR/2009/3/99

McCarthy et. al. 2001. McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J., & White, K.S. (eds.), 2001. Climate Change 2001: Impacts, Adaptation and Vulnerability, Cambridge University Press, Cambridge, 1032pp

Meat Board of Namibia, 2012, Annual Report 2012.

Meatco, 2012, Annual Report 2011/12.

Mendelsohn J., Jarvis Alice., Roberts Carole., and Robertson Tony. 2002. Atlas of Namibia.

Mendelson J. and Obeid, 2004. Forests and woodlands of Namibia

MET. 2001. Initial National Communication to the United Framework Convention on Climate Change. Available at http://unfccc.int/resource/docs/natc/namnc1.pdf.

MET. 2007. Second National Communication to the United Framework Convention on Climate Change. Available at http://unfccc.int/resource/docs/natc/namnc2.pdf

MET. 2015. Third National Communication to the United Framework Convention on Climate Change. Available at http://unfccc.int/resource/docs/natc/namnc3.pdf.

Midgley, G., Hughes, G., Thuiller, W., Drew, G. & Foden, W. 2005. Assessment of potential climate change impacts on Namibia's floristic diversity, ecosystem structure and function. Report for: Namibian National Biodiversity Programme, Directorate of Environmental Affairs by the Climate Change Research Group, South African National Biodiversity Institute (SANBI), Kirstenbosch Botanical Garden. Cape Town

Ministry of Agriculture, Water and Forestry., (Personal Communication) Burning AD Dept Forestry

Ministry of Agriculture, Water and Forestry., 2014. Annual report 2013-2014.

Ministry of Environment and Tourism, 2010. National Policy on Climate Change for Namibia

Ministry of Fisheries and Marine Resources., 2005. Annual report 2005

MoHSS, 2010. Namibia Malaria Strategic Plan 2010 – 2016. Ministry of Health and Social Security. 2010

Namibia (2011). Second National Communication to the United Nations Framework Convention on Climate. Ministry of Environment and Tourism, July 2011

Namibia Statistics Agency. 2012. Namibia 2011 Population and Housing Census Main Report. Republic of Namibia, Windhoek

Namibia Statistics Agency. 2012. Namibia Household Income & Expenditure Survey (NHIES) 2009/2010. Republic of Namibia, Windhoek

Namibia Statistics Agency. 2012. National Accounts 2000-2011. National Statistical Agency. Windhoek, Republic of Namibia

Namibia Statistics Agency. 2014. Namibia Population Projections 2011-2041. Census Main Report. Republic of Namibia, Windhoek, September 2014

Namibia Statistics Agency. 2014. National Accounts 2013. National Statistical Agency. Windhoek, Republic of Namibia

Namibia Statistics Agency (NSA), 2012. National Household Income and Expenditure Survey

Namibia Statistics Agency (NSA), 2013. Profile of Namibia

Namibia Statistics Agency (NSA), 2014a. Namibia 2011 Census Mortality Report

Namibia Statistics Agency (NSA), 2014b. Namibia 2013 Demographic and Health Survey, Main Report

National Planning Commission. 2002. Second National Development Plan (NDP2) 2002/2003 – 2006/2007. National Planning Commission, Windhoek, Republic of Namibia

National Planning Commission (2008). Third National Development Plan (NDP3) 2007/2008 – 2011/2012. National Planning Commission, Windhoek, Republic of Namibia

National Planning Commission. 2012. Third National Development Plan (NDP3) 2012/2013 – 2016/2017. National Planning Commission, Windhoek, Republic of Namibia

National Planning Commission. 2013. Annual economic development report 2012. National Planning Commission, Windhoek, Republic of Namibia

New et al. 2006. M. New, B. Hewitson, D.B. Stephenson, A. Tsiga, A. Kruger, A. Manhique, R. Lajoie. Evidence of trends in daily climate extremes over southern and west Africa. J. Geophys. Res. Atmos., 111 (D14) (2006), pp. 1984-2012

NSA. 2015. *Namibia Statistics Agency (NSA): Namibia Population and Housing Census Data.* Windhoek, Namibia: NSA

Parry ML,Carter TR. 1998.Climate impact and adaptation assessment:a guide to the IPCC approach. London, Earthscan Publications

Republic of Namibia. 2004. Namibia Vision 2030 – Policy Framework for Long-term National Development Main Document. Office of the President. Windhoek, Republic of Namibia

Republic of Namibia. 2011 Namibia Second National Communication to the United Nations Framework Convention on Climate Change. Ministry of Environment and Tourism

Routhauge A., 2014. Baseline Assessment for the De-Bushing Programme in Namibia.

Schoeman S.J., 1996. Characterization of beef cattle breeds by virtue of their performance in the National Beef Cattle Performance and Progeny Testing Scheme, South African Journal of Animal Science, 1996, 26 (1)

Schroter et.al. 2005. Ecosystem Service Supply and Vulnerability to Global Change in Europe. Science 310:1333-1337

Smit, B., et al. 2001. Adaptation to climate change in the context of sustainable development and equity. In J.J. McCarthy and O.F. Canziani, eds., Climate Change 2001: Impacts, adaptation and vulnerability. Contribution of Working Group III to the 3rd Assessment Report of the Intergovernmental Panel on Climate Change

Theron et. al. 2010. André Theron, A.K., Rossouw, M., Barwell, L., Maherry, A., Diedericks, G. and de Wet, P., 2010.Quantification of risks to coastal areas and development: wave run-up and erosion. CSIR Science real and relevant conference 2010

Trading economics. 2014. Namibia GDP Annual Growth Rate. (1990-2013) http://www.tradingeconomics.com/namibia/gdp-growth

United Nations, Department of Economic and Social Affairs, Population Division. 2013. "World Population Prospects: The 2012 Revision. File POP/1-1: Total population (both sexes combined) by major area, region and country, annually for 1950-2100. United Nations. 2013

von Maltitz et. al. 2005. von Maltitz, G., Scholes, B & Midgley, G. 2005. Impacts and adaptations to climate change by the biodiversity sector in southern Africa. SIR, Environmental and South African Natural Biodiversity Institute (SANBI)

Warburton, M.L., Schulze, R.E., 2005. Chapter 15: Detection of Climate Change: A Review of Literature on Changes in Temperature, Rainfall and Streamflow, on Detection Methods and Data Problems, pp257 274. [In: Schulze, R.E., (ed) Climate Change and Water Resources in southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation. Water Research Commission, Pretoria, RSA, WRC Report 1430/1/05].

Weber, B. M. and J. M. Mendelsohn. 2017. Informal Settlements in Namibia: their nature and growth Exploring ways to make Namibian urban development more socially just and inclusive. Windhoek: Development Workshop Namibia. Retrieved from: http://dw-namibia.org/wp-content/uploads/2017/11/Informalsettlements-in-Namibia-their-nature-and-growth-DWN-2017.pdf

Wikipedia. 2015. Demographics of Namibia. http://www.wikipedia.org/wiki

Wikipedia. 2015. Middle income trap. http://www.wikipedia.org/wiki

Willemse, N. E. 2018. *Stocktaking of existing and planned Climate Change Adaptation (CCA) initiatives and programs that contribute to NDC implementation in Namibia.* Windhoek: GiZ

World Bank. 2014. Updated income classification of data. http://www. data.worldbank.org/news/2015-country-classifications

World Bank. 2015. Country and lending groups. http://www.data.worldbank.org/about/country-and-lending-groups

World Bank. 2015. GDP per capita (current US$). file:///C:/Namibia 2015/GDP per capita (current US$)_Data_Table.htm

Yohe, Gary & Tol, Richard. 2001. Indicators for Social and Economic Coping Capacity- Moving Toward a Working Definition of Adaptive Capacity. Global Environmental Change. 12. 25-40

9. Appendices

Appendix A.1: Ranking of constituencies based on the Exposure Index

Constituency	Exposure Scores	Rank	Constituency	Exposure Scores	Rank
Walvis Bay Rural	7.16	1	Ongenga	3.79	62
Orangemund	6.30	2	Kalahari	3.78	63
Rehoboth Rural	6.00	3	Omuthiyagwiipundi	3.78	64
Judea Lyaboloma	5.88	4	Oniipa	3.78	65
Kabbe North	5.85	5	Ohangwena	3.77	66
Kongola	5.84	6	Eengondi	3.76	67
Linyanti	5.81	7	Swakopmund	3.76	68
Sibbinda	5.81	8	Ncuncuni	3.75	69
Kabbe South	5.78	9	Okongo	3.72	70
Katima Mulilo Urban	5.78	10	Onayena	3.69	71
Karibib	5.70	11	Gobabis	3.66	72
Omaruru	5.67	12	Epembe	3.64	73
Windhoek Rural	5.65	13	Oshikunde	3.64	74
Katima Mulilo Rural	5.64	14	Okaku	3.64	75
Mankumpi	5.58	15	Ongwediva	3.64	76
Berseba	5.55	16	Okankolo	3.60	77
Ncamagoro	5.52	17	Karasburg East	3.58	78
Daweb	5.44	18	Eenhana	3.56	79
Tondoro	5.33	19	Engela	3.56	80
Grootfontein	5.29	20	Omulonga	3.56	81
Rundu Rural	5.12	21	Khorixas	3.55	82
Onyaanya	5.12	22	Okatyali	3.55	83
Mashare	5.02	23	Ompundja	3.55	84
Guinas	4.96	24	Uukwiyu	3.55	85
Mariental Urban	4.93	25	Okatana	3.55	86
Okahandja	4.83	26	Omundaungilo	3.54	87
Ndiyona	4.76	27	Oshikango	3.54	88
Kamanjab	4.74	28	Omuntele	3.53	89
Mariental Rural	4.73	29	Endola	3.48	90
Omatako	4.71	30	Ondangwa Rural	3.48	91
Windhoek West	4.68	31	Ondangwa Urban	3.48	92
Daures	4.67	32	Oshakati East	3.48	93
Katutura East	4.58	33	Oshakati West	3.48	94
Samora Machel	4.58	34	Keetmanshoop Urban	3.46	95
Ndonga Linena	4.58	35	Keetmanshoop Rural	3.36	96
Musese	4.56	36	Elim	3.33	97
Kapako	4.56	37	Ruacana	3.33	98
!Nami -= Nus	4.54	38	Uuvudhiya	3.33	99
Gibeon	4.52	39	Ondobe	3.32	100
Epukiro	4.50	40	Otamanzi	3.32	101
Aranos	4.37	41	Karasburg West	3.29	102
Otjombinde	4.36	42	Otjiwarongo	3.28	103
Rundu Urban	4.26	43	Tsandi	3.19	104
Tobias Hainyeko	4.26	44	Engela	3.18	105
Katutura Central	4.26	45	Etayi	3.18	106
Khomasdal	4.26	46	Okahao	3.18	107
Windhoek East	4.26	47	Ogongo	3.14	108
Moses ||Garoëb	4.26	48	Okakarara	3.14	109
Otjinene	4.24	49	Opuwo Rural	3.12	110
Rehoboth West Urban	4.21	50	Walvis Bay Urban	3.09	111
Outjo	4.20	51	Okalongo	3.06	112
Rehoboth East Urban	4.19	52	Onesi	3.06	113
Otavi	4.17	53	Oshikuku	3.02	114
Tsumkwe	4.11	54	Anamulenge	2.99	115
Olukonda	4.10	55	Outapi	2.99	116
Mpungu	3.89	56	Arandis	2.93	117
Aminuis	3.89	57	Sesfontein	2.87	118
Nkurenkure	3.86	58	Epupa	2.81	119
Nehale LyaMpingana	3.86	59	Opuwo Urban	2.81	120
Tsumeb	3.84	60	Mukwe	2.68	121
Okorukambe	3.80	61	John Pandeni	2.58	122

Appendix A.2: Ranking of constituencies based on the Sensitivity Index

Constituency	Sensitivity Scores	Rank	Constituency	Sensitivity Scores	Rank
Epupa	39.0406	1	Olukonda	6.6794	62
Onesi	36.6640	2	Okahao	6.6681	63
Opuwo Rural	24.8023	3	Windhoek West	6.5168	64
Elim	23.9351	4	Katima Mulilo Urban	6.2278	65
Ruacana	21.1856	5	Grootfontein	6.1667	66
Otamanzi	21.1856	6	Musese	6.1540	67
Tondoro	20.7821	7	Katutura Central	6.0161	68
Ndiyona	17.7061	8	Outjo	5.7096	69
Okalongo	17.3554	9	Okahandja	5.4382	70
Endola	16.7542	10	Ondangwa Rural	5.3626	71
Mukwe	16.1645	11	Uuvudhiya	5.3314	72
Epembe	15.7557	12	Daures	5.3001	73
Omuntele	15.4621	13	Tobias Hainyeko	4.9489	74
Oshikuku	15.1983	14	Tsumeb	4.9488	75
Tsandi	15.0620	15	Rehoboth Rural	4.9310	76
Omulonga	14.5541	16	Omuthiyagwiipundi	4.9213	77
Kapako	13.8547	17	Nehale LyaMpingana	4.9041	78
Eengondi	13.6305	18	Aminuis	4.8500	79
Khorixas	13.3642	19	Onyaanya	4.8482	80
Samora Machel	13.1594	20	!Nami -= Nus	4.8445	81
Eenhana	13.0451	21	Engela	4.7692	82
Okongo	12.9826	22	Ondangwa Urban	4.7517	83
Onayena	12.8551	23	Windhoek Rural	4.7133	84
Mashare	12.5867	24	Otjombinde	4.7001	85
Ncamagoro	12.2331	25	Kamanjab	4.4810	86
Windhoek East	12.1099	26	Otjinene	4.4727	87
Ondobe	12.1011	27	Kabbe South	4.4458	88
Ndonga Linena	11.8040	28	Oshakati West	4.4326	89
Anamulenge	11.5422	29	Gobabis	4.3629	90
Engela	11.3057	30	Karasburg East	4.3072	91
Ongwediva	10.8652	31	Nkurenkure	4.1027	92
Oshikunde	10.6016	32	Katutura East	4.0870	93
Oshikango	10.4917	33	Judea Lyaboloma	4.0146	94
Mankumpi	10.2567	34	Ohangwena	3.9384	95
Guinas	9.9149	35	Mariental Rural	3.8144	96
Khomasdal	9.9087	36	Otjiwarongo	3.8021	97
Moses ||Garoëb	9.8892	37	Ncuncuni	3.6481	98
John Pandeni	9.5222	38	Omatako	3.4959	99
Okakarara	9.3951	39	Okankolo	3.4798	100
Swakopmund	9.3541	40	Linyanti	3.4033	101
Walvis Bay Urban	9.0661	41	Outapi	3.3659	102
Etayi	8.8263	42	Okatana	3.2396	103
Sibbinda	8.7769	43	Mariental Urban	3.2148	104
Ogongo	8.6985	44	Keetmanshoop Urban	3.0983	105
Katima Mulilo Rural	8.6539	45	Rundu Urban	3.0472	106
Okatyali	8.4571	46	Berseba	2.9720	107
Mpungu	8.3911	47	Karasburg West	2.9201	108
Kalahari	8.3418	48	Karibib	2.8719	109
Ongenga	8.2224	49	Gibeon	2.6344	110
Oshakati East	8.0263	50	Epukiro	2.6207	111
Oniipa	7.9665	51	Daweb	2.6069	112
Omundaungilo	7.9148	52	Omaruru	2.5782	113
Otavi	7.7045	53	Rehoboth East Urban	2.5053	114
Kongola	7.6801	54	Keetmanshoop Rural	2.4783	115
Opuwo Urban	7.3944	55	Sesfontein	2.2975	116
Rundu Rural	7.1102	56	Orangemund	2.2926	117
Okaku	7.0798	57	Arandis	2.1215	118
Uukwiyu	6.8402	58	Rehoboth West Urban	2.0443	119
Okorukambe	6.8011	59	Ompundja	2.0297	120
Walvis Bay Rural	6.7453	60	Kabbe North	1.3119	121
Tsumkwe	6.6929	61	Aranos	1.1726	122

Appendix A.3: Ranking of constituencies based on the Adaptive Capacity index

Constituency	Adaptive capacity Scores	Rank	Constituency	Adaptive capacity Scores	Rank
Epupa	56.5670	1	Okalongo	10.3507	62
Samora Machel	48.6260	2	Oshakati West	10.3422	63
Windhoek East	37.3205	3	Ongenga	10.1166	64
Khomasdal	34.1070	4	Eenhana	9.8366	65
Ncamagoro	32.5993	5	Onyaanya	9.7346	66
Mankumpi	30.1951	6	Rundu Urban	9.3870	67
Kalahari	28.4667	7	Engela	9.3224	68
Katima Mulilo Urban	27.7527	8	Etayi	9.2464	69
Guinas	26.8756	9	Epembe	9.1070	70
Omuntele	26.6755	10	Mariental Urban	8.8754	71
Mashare	26.3534	11	Oshikango	8.8267	72
Swakopmund	26.1201	12	Otjombinde	8.5144	73
Ndiyona	24.7381	13	Mariental Rural	8.4601	74
Daweb	23.0044	14	Omundaungilo	8.2862	75
Okongo	22.3344	15	Oshikuku	7.7991	76
Tondoro	22.0956	16	Okorukambe	7.7370	77
Tsumkwe	22.0395	17	Linyanti	7.7357	78
Sibbinda	19.9563	18	Ondangwa Urban	7.6250	79
Walvis Bay Rural	19.5805	19	Anamulenge	7.6246	80
Mukwe	18.9587	20	Okaku	7.3169	81
Eengondi	18.3587	21	Omatako	7.1951	82
Musese	18.1171	22	Omulonga	7.0744	83
Katima Mulilo Rural	17.8726	23	Nehale LyaMpingana	7.0600	84
Epukiro	17.8006	24	Moses ||Garoëb	7.0547	85
Gobabis	17.6404	25	Daures	6.9789	86
Mpungu	17.5689	26	Ondangwa Rural	6.9342	87
Onesi	17.3466	27	Okahao	6.7786	88
Onayena	17.1652	28	Otjinene	6.7419	89
Walvis Bay Urban	16.6995	29	Otjiwarongo	6.6670	90
Ndonga Linena	16.4921	30	Ogongo	6.2889	91
Kabbe South	16.4308	31	Aminuis	6.0276	92
Grootfontein	16.0958	32	Omuthiyagwiipundi	5.4740	93
Tsandi	15.1361	33	Olukonda	5.4153	94
Kapako	14.7304	34	Sesfontein	5.2106	95
Rehoboth Rural	14.6630	35	Uukwiyu	5.0712	96
Ruacana	14.2924	36	Katutura East	4.8750	97
Rehoboth East Urban	14.2110	37	Tsumeb	4.8505	98
Rundu Rural	14.0804	38	Karasburg East	4.7564	99
Opuwo Rural	14.0724	39	Kabbe North	4.7220	100
Otamanzi	13.8924	40	Gibeon	4.6836	101
Endola	13.8394	41	!Nami -= Nus	4.5075	102
Oniipa	13.8081	42	Tobias Hainyeko	4.3583	103
John Pandeni	13.5867	43	Engela	4.2280	104
Ondobe	13.1885	44	Berseba	4.0373	105
Oshakati East	13.1315	45	Karibib	3.9640	106
Okakarara	13.1218	46	Omaruru	3.7689	107
Kongola	13.0911	47	Windhoek Rural	3.7152	108
Katutura Central	12.9209	48	Okatana	3.7074	109
Outjo	12.6470	49	Okankolo	3.3194	110
Nkurenkure	12.0780	50	Keetmanshoop Rural	3.2261	111
Windhoek West	11.8910	51	Orangemund	3.1013	112
Judea Lyaboloma	11.7753	52	Keetmanshoop Urban	2.9576	113
Oshikunde	11.5415	53	Ohangwena	2.9442	114
Otavi	11.4659	54	Arandis	2.7907	115
Khorixas	11.3808	55	Rehoboth West Urban	2.7712	116
Ncuncuni	11.1006	56	Uuvudhiya	2.5818	117
Elim	11.0758	57	Aranos	2.5205	118
Opuwo Urban	11.0736	58	Ompundja	2.0890	119
Ongwediva	10.7240	59	Outapi	2.0380	120
Kamanjab	10.4704	60	Okatyali	1.9100	121
Okahandja	10.4537	61	Karasburg West	1.8529	122

Appendix A.4: Ranking of constituencies based on the NCCVI

Constituency	NCCVI Scores	Rank	Constituency	NCCVI Scores	Rank
Samora Machel	7.4200	1	Linyanti	0.6500	62
Epupa	5.1500	2	Keetmanshoop Rural	0.6500	63
Khomasdal	5.0000	3	Ncamagoro	0.6500	64
Onesi	4.4200	4	Ohangwena	0.6500	65
Opuwo Rural	3.6300	5	Aminuis	0.6500	66
Tsumkwe	3.1900	6	Ondangwa Rural	0.6400	67
Ruacana	3.0300	7	Okakarara	0.6400	68
Otamanzi	3.0000	8	Eenhana	0.6200	69
Kalahari	2.6200	9	Kabbe North	0.6100	70
Daures	2.5900	10	Berseba	0.6100	71
Ndiyona	2.1900	11	!Nami -= Nus	0.6100	72
Mukwe	2.1000	12	Okorukambe	0.6100	73
Omuntele	1.9300	13	Tsumeb	0.6100	74
Okalongo	1.6100	14	Oniipa	0.6100	75
Daweb	1.5100	15	Omundaungilo	0.6000	76
Tsandi	1.3800	16	Musese	0.5900	77
Okongo	1.2900	17	Omulonga	0.5700	78
Katima Mulilo Rural	1.2500	18	Okatyali	0.5600	79
Judea Lyaboloma	1.2000	19	Engela	0.5500	80
Guinas	1.2000	20	Ongenga	0.5500	81
Kabbe South	1.1800	21	Nkurenkure	0.5400	82
Mashare	1.1800	22	Kapako	0.5300	83
Gobabis	1.1700	23	Engela	0.5300	84
Katima Mulilo Urban	1.1100	24	Ompundja	0.5100	85
Sibbinda	1.0300	25	Karasburg East	0.5000	86
Kongola	0.9900	26	Omatako	0.4800	87
Tondoro	0.9800	27	Okahandja	0.4700	88
Grootfontein	0.9800	28	Otjiwarongo	0.4700	89
Tobias Hainyeko	0.9500	29	Rehoboth Rural	0.4400	90
Otjinene	0.9500	30	Orangemund	0.4400	91
Anamulenge	0.9400	31	Windhoek Rural	0.4400	92
Rundu Urban	0.9300	32	Karasburg West	0.4300	93
Okaku	0.9300	33	Olukonda	0.4200	94
Mankumpi	0.9200	34	Mariental Rural	0.4000	95
Ondobe	0.9200	35	Rundu Rural	0.4000	96
Oshikango	0.9100	36	Sesfontein	0.4000	97
Elim	0.9100	37	Katutura East	0.3900	98
Okatana	0.9100	38	Omuthiyagwiipundi	0.3700	99
Uukwiyu	0.9100	39	Arandis	0.3500	100
Opuwo Urban	0.9000	40	Karibib	0.3500	101
Eengondi	0.9000	41	Omaruru	0.3500	102
Outapi	0.8900	42	Oshikunde	0.3500	103
Nehale LyaMpingana	0.8900	43	Walvis Bay Rural	0.3300	104
Epembe	0.8800	44	Ogongo	0.3200	105
Ndonga Linena	0.8700	45	Okahao	0.3200	106
Endola	0.8500	46	Windhoek West	0.3100	107
Ncuncuni	0.8400	47	Etayi	0.2900	108
Katutura Central	0.8400	48	Outjo	0.2700	109
Khorixas	0.7900	49	Oshakati East	0.2600	110
Oshikuku	0.7900	50	Rehoboth West Urban	0.2500	111
Onayena	0.7700	51	Walvis Bay Urban	0.2400	112
Gibeon	0.7500	52	Mariental Urban	0.2400	113
Otavi	0.7500	53	John Pandeni	0.2400	114
Mpungu	0.7400	54	Ongwediva	0.2400	115
Moses ||Garoëb	0.7400	55	Onyaanya	0.2400	116
Aranos	0.7100	56	Rehoboth East Urban	0.2300	117
Epukiro	0.7000	57	Oshakati West	0.2200	118
Otjombinde	0.6900	58	Keetmanshoop Urban	0.2100	119
Uuvudhiya	0.6900	59	Swakopmund	0.2000	120
Kamanjab	0.6800	60	Ondangwa Urban	0.1800	121
Okankolo	0.6600	61	Windhoek East	0.1000	122

Appendix B.1: The Exposure of Constituencies to Climate Change Risks/Threats

	Level of Exposure to Climate Change Risks/Threats				
Erongo	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Arandis	x				
Daures				x	
Karibib					x
Omaruru					x
Swakopmund			x		
Walvis Bay Rural					x
Walvis Bay Urban	x				
Hardap	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Aranos				x	
Daweb					x
Gibeon				x	
Mariental Rural				x	
Mariental Urban					x
Rehoboth East Urban			x		
Rehoboth Rural					x
Rehoboth West Urban				x	
Karas	**Very Low**	**Low**	**Medium**	**High**	**Very High**
!Nami -= Nus				x	
Berseba					x
Karasburg East		x			
Karasburg West	x				
Keetmanshoop Rural		x			
Keetmanshoop Urban		x			
Orangemund					x
Kavango East/West	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Kapako				x	
Mankumpi					x
Mashare					x
Mpungu			x		
Mukwe	x				
Musese				x	
Ncamagoro					x
Ncuncuni			x		
Ndiyona				x	
Ndonga Linena				x	
Nkurenkure			x		
Rundu Rural					x
Rundu Urban				x	
Tondoro					x
Khomas	**Very Low**	**Low**	**Medium**	**High**	**Very High**
John Pandeni	x				
Katutura Central				x	
Katutura East				x	
Khomasdal				x	
Moses ||Garoëb				x	
Samora Machel				x	
Tobias Hainyeko				x	
Windhoek East				x	
Windhoek Rural					x
Windhoek West				x	
Kunene	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Epupa	x				
Kamanjab				x	
Khorixas		x			
Opuwo Rural	x				
Opuwo Urban	x				
Outjo			x		
Sesfontein	x				
Ohangwena	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Eenhana		x			
Endola		x			
Engela		x			
Epembe		x			
Ohangwena			x		
Okongo		x			
Omulonga		x			
Omundaungilo		x			

	Level of Exposure to Climate Change Risks/Threats				
Ondobe	x				
Ongenga			x		
Oshikango		x			
Oshikunde		x			
Omaheke	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Aminuis			x		
Epukiro				x	
Gobabis		x			
Kalahari			x		
Okorukambe			x		
Otjinene				x	
Otjombinde				x	
Omusati	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Anamulenge	x				
Elim		x			
Engela	x				
Etayi	x				
Ogongo	x				
Okahao	x				
Okalongo	x				
Onesi	x				
Oshikuku	x				
Otamanzi	x				
Outapi	x				
Ruacana	x				
Tsandi	x				
Oshana	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Okaku		x			
Okatana		x			
Okatyali		x			
Ompundja		x			
Ondangwa Rural		x			
Ondangwa Urban		x			
Ongwediva		x			
Oshakati East		x			
Oshakati West		x			
Uukwiyu		x			
Uuvudhiya	x				
Oshikoto	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Eengondi			x		
Guinas					x
Nehale LyaMpingana			x		
Okankolo		x			
Olukonda			x		
Omuntele		x			
Omuthiyagwiipundi			x		
Onayena		x			
Oniipa			x		
Onyaanya					x
Tsumeb			x		
Otjozondjupa	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Grootfontein					x
Okahandja				x	
Okakarara	x				
Omatako				x	
Otavi			x		
Otjiwarongo	x				
Tsumkwe			x		
Zambezi	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Judea Lyaboloma					x
Kabbe North					x
Kabbe South					x
Katima Mulilo Rural					x
Katima Mulilo Urban					x
Kongola					x
Linyanti					x
Sibbinda					x

Appendix B.2: The Sensitivity of Constituencies to Climate Change Risks/Threats

	Sensitivity to Climate Change Risks/Threats				
Erongo	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Arandis	x				
Daures		x			
Karibib	x				
Omaruru	x				
Swakopmund				x	
Walvis Bay Rural			x		
Walvis Bay Urban				x	
Hardap	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Aranos	x				
Daweb	x				
Gibeon	x				
Mariental Rural		x			
Mariental Urban	x				
Rehoboth East Urban	x				
Rehoboth Rural		x			
Rehoboth West Urban	x				
Karas	**Very Low**	**Low**	**Medium**	**High**	**Very High**
!Nami -= Nus		x			
Berseba	x				
Karasburg East		x			
Karasburg West	x				
Keetmanshoop Rural	x				
Keetmanshoop Urban	x				
Orangemund	x				
Kavango East/West	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Kapako					x
Mankumpi				x	
Mashare					x
Mpungu				x	
Mukwe					x
Musese			x		
Ncamagoro					x
Ncuncuni	x				
Ndiyona					x
Ndonga Linena				x	
Nkurenkure		x			
Rundu Rural			x		
Rundu Urban	x				
Tondoro					x
Khomas	**Very Low**	**Low**	**Medium**	**High**	**Very High**
John Pandeni				x	
Katutura Central			x		
Katutura East		x			
Khomasdal				x	
Moses ||Garoëb				x	
Samora Machel					x
Tobias Hainyeko		x			
Windhoek East				x	
Windhoek Rural		x			
Windhoek West			x		
Kunene	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Epupa					x
Kamanjab		x			
Khorixas					x
Opuwo Rural					x
Opuwo Urban			x		
Outjo			x		
Sesfontein	x				
Ohangwena	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Eenhana					x
Endola					x
Engela		x			
Epembe					x
Ohangwena		x			
Okongo					x
Omulonga					x
Omundaungilo			x		

Sensitivity to Climate Change Risks/Threats					
Ondobe				x	
Ongenga				x	
Oshikango				x	
Oshikunde				x	
Omaheke	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Aminuis		x			
Epukiro	x				
Gobabis		x			
Kalahari				x	
Okorukambe			x		
Otjinene		x			
Otjombinde		x			
Omusati	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Anamulenge				x	
Elim					x
Engela				x	
Etayi				x	
Ogongo				x	
Okahao			x		
Okalongo					x
Onesi					x
Oshikuku					x
Otamanzi					x
Outapi	x				
Ruacana					x
Tsandi					x
Oshana	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Okaku			x		
Okatana	x				
Okatyali				x	
Ompundja	x				
Ondangwa Rural		x			
Ondangwa Urban		x			
Ongwediva				x	
Oshakati East				x	
Oshakati West		x			
Uukwiyu			x		
Uuvudhiya		x			
Oshikoto	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Eengondi					x
Guinas				x	
Nehale LyaMpingana		x			
Okankolo	x				
Olukonda			x		
Omuntele					x
Omuthiyagwiipundi		x			
Onayena					x
Oniipa			x		
Onyaanya		x			
Tsumeb		x			
Otjozondjupa	**1**	**2**	**3**	**1**	**0**
Grootfontein			x		
Okahandja		x			
Okakarara				x	
Omatako	x				
Otavi			x		
Otjiwarongo		x			
Tsumkwe			x		
Zambezi	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Judea Lyaboloma		x			
Kabbe North	x				
Kabbe South		x			
Katima Mulilo Rural				x	
Katima Mulilo Urban			x		
Kongola			x		
Linyanti	x				
Sibbinda				x	

Appendix B.3: The Adaptive Capacity of Constituencies to Climate Change Risks/Threats

Adaptive Capacity to Climate Change Risks/Threats					
Erongo	**Very High**	**High**	**Medium**	**Low**	**Very Low**
Arandis	x				
Daures		x			
Karibib	x				
Omaruru	x				
Swakopmund					x
Walvis Bay Rural					x
Walvis Bay Urban				x	
Hardap	**Very High**	**High**	**Medium**	**Low**	**Very Low**
Aranos	x				
Daweb					x
Gibeon	x				
Mariental Rural		x			
Mariental Urban		x			
Rehoboth East Urban				x	
Rehoboth Rural				x	
Rehoboth West Urban	x				
Karas	**Very High**	**High**	**Medium**	**Low**	**Very Low**
!Nami -= Nus	x				
Berseba	x				
Karasburg East	x				
Karasburg West	x				
Keetmanshoop Rural	x				
Keetmanshoop Urban	x				
Orangemund	x				
Kavango East/West	**Very High**	**High**	**Medium**	**Low**	**Very Low**
Kapako				x	
Mankumpi					x
Mashare					x
Mpungu				x	
Mukwe					x
Musese					x
Ncamagoro					x
Ncuncuni			x		
Ndiyona					x
Ndonga Linena				x	
Nkurenkure				x	
Rundu Rural				x	
Rundu Urban			x		
Tondoro					x
Khomas	**Very High**	**High**	**Medium**	**Low**	**Very Low**
John Pandeni				x	
Katutura Central				x	
Katutura East		x			
Khomasdal					x
Moses ||Garoëb		x			
Samora Machel					x
Tobias Hainyeko	x				
Windhoek East					x
Windhoek Rural	x				
Windhoek West			x		
Kunene	**Very High**	**High**	**Medium**	**Low**	**Very Low**
Epupa					x
Kamanjab			x		
Khorixas			x		
Opuwo Rural				x	
Opuwo Urban			x		
Outjo				x	
Sesfontein		x			
Ohangwena	**Very High**	**High**	**Medium**	**Low**	**Very Low**
Eenhana			x		
Endola				x	
Engela	x				
Epembe		x			
Ohangwena	x				
Okongo					x

Adaptive Capacity to Climate Change Risks/Threats					
Omulonga		x			
Omundaungilo		x			
Ondobe				x	
Ongenga			x		
Oshikango		x			
Oshikunde			x		
Omaheke	**Very High**	**High**	**Medium**	**Low**	**Very Low**
Aminuis		x			
Epukiro					x
Gobabis					x
Kalahari					x
Okorukambe		x			
Otjinene		x			
Otjombinde		x			
Omusati	**Very High**	**High**	**Medium**	**Low**	**Very Low**
Anamulenge		x			
Elim			x		
Engela			x		
Etayi			x		
Ogongo		x			
Okahao		x			
Okalongo			x		
Onesi				x	
Oshikuku		x			
Otamanzi				x	
Outapi	x				
Ruacana				x	
Tsandi				x	
Oshana	**Very High**	**High**	**Medium**	**Low**	**Very Low**
Okaku		x			
Okatana	x				
Okatyali	x				
Ompundja	x				
Ondangwa Rural		x			
Ondangwa Urban		x			
Ongwediva			x		
Oshakati East				x	
Oshakati West			x		
Uukwiyu		x			
Uuvudhiya	x				
Oshikoto	**Very High**	**High**	**Medium**	**Low**	**Very Low**
Eengondi					x
Guinas					x
Nehale LyaMpingana		x			
Okankolo	x				
Olukonda		x			
Omuntele					x
Omuthiyagwiipundi		x			
Onayena				x	
Oniipa				x	
Onyaanya			x		
Tsumeb	x				
Otjozondjupa	**Very High**	**High**	**Medium**	**Low**	**Very Low**
Grootfontein				x	
Okahandja			x		
Okakarara				x	
Omatako		x			
Otavi			x		
Otjiwarongo		x			
Tsumkwe					x
Zambezi	**Very High**	**High**	**Medium**	**Low**	**Very Low**
Judea Lyaboloma			x		
Kabbe North	x				
Kabbe South				x	
Katima Mulilo Rural					x
Katima Mulilo Urban					x
Kongola				x	
Linyanti		x			
Sibbinda					x

Appendix B.4: The Vulnerability of Constituencies to Climate Change Risks/Threats

Vulnerability to Climate Change Risks/Threats					
Erongo	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Arandis	x				
Daures					x
Karibib	x				
Omaruru	x				
Swakopmund	x				
Walvis Bay Rural	x				
Walvis Bay Urban	x				
Hardap	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Aranos			x		
Daweb					x
Gibeon			x		
Mariental Rural		x			
Mariental Urban	x				
Rehoboth East Urban	x				
Rehoboth Rural		x			
Rehoboth West Urban	x				
Karas	**Very Low**	**Low**	**Medium**	**High**	**Very High**
!Nami -= Nus		x			
Berseba		x			
Karasburg East		x			
Karasburg West		x			
Keetmanshoop Rural			x		
Keetmanshoop Urban	x				
Orangemund		x			
Kavango East/West	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Kapako		x			
Mankumpi				x	
Mashare					x
Mpungu			x		
Mukwe					x
Musese		x			
Ncamagoro			x		
Ncuncuni				x	
Ndiyona					x
Ndonga Linena				x	
Nkurenkure		x			
Rundu Rural		x			
Rundu Urban				x	
Tondoro				x	
Khomas	**Very Low**	**Low**	**Medium**	**High**	**Very High**
John Pandeni	x				
Katutura Central				x	
Katutura East	x				
Khomasdal					x
Moses ||Garoëb			x		
Samora Machel					x
Tobias Hainyeko				x	
Windhoek East	x				
Windhoek Rural		x			
Windhoek West	x				
Kunene	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Epupa					x
Kamanjab			x		
Khorixas				x	
Opuwo Rural					x
Opuwo Urban				x	
Outjo	x				
Sesfontein		x			
Ohangwena	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Eenhana			x		
Endola				x	
Engela		x			
Embed				x	
Ohangwena			x		
Okongo					x

Vulnerability to Climate Change Risks/Threats					
Omulonga		x			
Omundaungilo		x			
Ondobe				x	
Ongenga		x			
Oshikango				x	
Oshikunde	x				
Omaheke	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Aminuis			x		
Epukiro			x		
Gobabis					x
Kalahari					x
Okorukambe		x			
Otjinene				x	
Otjombinde			x		
Omusati	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Anamulenge				x	
Elim				x	
Engela		x			
Etayi	x				
Ogongo	x				
Okahao	x				
Okalongo					x
Onesi					x
Oshikuku				x	
Otamanzi					x
Outapi				x	
Ruacana					x
Tsandi					x
Oshana	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Okaku				x	
Okatana				x	
Okatyali		x			
Ompundja		x			
Ondangwa Rural			x		
Ondangwa Urban	x				
Ongwediva	x				
Oshakati East	x				
Oshakati West	x				
Uukwiyu				x	
Uuvudhiya			x		
Oshikoto	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Eengondi				x	
Guinas					x
Nehale LyaMpingana				x	
Okankolo			x		
Olukonda		x			
Omuntele					x
Omuthiyagwiipundi	x				
Onayena			x		
Oniipa		x			
Onyaanya	x				
Tsumeb		x			
Otjozondjupa	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Grootfontein				x	
Okahandja		x			
Okakarara			x		
Omatako		x			
Otavi			x		
Otjiwarongo		x			
Tsumkwe					x
Zambezi	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Judea Lyaboloma					x
Kabbe North		x			
Kabbe South					x
Katima Mulilo Rural					x
Katima Mulilo Urban					x
Kongola				x	
Linyanti			x		
Sibbinda					x