LIMPOPO

PROVINCIAL GOVERNMENT

REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF

ECONOMIC DEVELOPMENT, ENVIRONMENT & TOURISM

PROVINCIAL CLIMATE CHANGE RESPONSE STRATEGY

2016 – 2020

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Foreword

It gives me great pleasure to present this cross-sectorial climate change strategy, the Limpopo Climate Change Strategy (LCCS) 2016 – 2020. This is a culmination of efforts from various role players who through numerous workshops and other means played their part and contributed to the development of the strategy.

Limpopo recognises that climate change is one of the greatest long term challenges facing the world today. The consequences of extreme events experienced in recent times have highlighted the need for greater preparation of the Province to handle climate variations and for the implementation of frameworks and strategies to address mitigation and adaptation. A future of uncontrolled climate change will mean that flooding, heat waves and unpredictable weather will continue to create upheaval in our province, with already vulnerable residents most at risk.

This strategy sets out Limpopo's ambitions to embrace the challenges that climate change will bring in a positive and proactive way. It acknowledges the magnitude of this issue on the planet and the impacts this will have across the world. However, the main aim of this strategy is to address this global issue at a local level in a way which will benefit people, the economy and environment locally.

This will be an evolving strategy providing a framework through which partners across the Province can work together to reduce their carbon emissions, address the challenges, and take advantage of the opportunities that a changing climate will bring.

A lot of effort has been made to ensure that we are working together across the province in a co-ordinated way to tackle climate change. So we are proud to have joined together to continue to forge a pathway towards sustaining and improving the quality of life of those who live and work in Limpopo far into the future, through setting out our clear priority to play our part in tackling global climate change. We have worked together as a partnership to create a strategy that spans the priorities of a range of groups and organs in the province.

This strategy clearly sets out the strategic measures to reduce greenhouse gas emissions, adapt to the inevitable climate change and ensure that energy is provided and used in a sustainable way within the Province. Appropriate actions that are both ambitious and achievable to ensure accomplishment of these response measures will be identified and implemented through collaboration and effective communication across all sectors. Let us continue to work in partnership to deliver on this strategy. I thank everyone in advance for their involvement in the hard work ahead.

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MEMBER OF EXECUTIVE COUNCIL

LIMPOPO DEPARTMENT OF ECONOMIC DEVELOPMENT ENVIRONMENT AND TOURISM (LEDET)

Acknowledgement

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VULNERABILTIY ASSESSMENT AND ADAPTATION STRATEGIES

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GREENHOUSE GAS EMISSION INVENTORY AND MITIGATION STRATEGIES

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Executive Summary

There is now a strong consensus amongst scientific community that anthropogenic emissions of greenhouse gases, which absorb and trap heat in the Earth's atmosphere, is causing the global climate to change at an unprecedented scale and speed. The observed warming of the atmosphere and ocean over the last 50 years has taken the global temperature outside the range of natural variability as simulated by climate models. The latest predictions suggest that, globally, temperatures could rise between 1.1°C and 6.4°C by 2100. Regional variations can be even greater. The nature of climate change is such that different regions in the world experience varied effects. Economically well-off countries have the means to adapt to the effects of climate change, while much poorer countries do not have the means to cushion themselves from such effects of climate change. Even in the context of South Africa which itself is a Developing Country, relatively poorer provinces such as Limpopo are more vulnerable to the effects of climate change.

South Africa is located in one of the three regions of the African continent that will most likely suffer significant adverse impacts progressively warmer and drier summers, wetter and milder winters and more frequent extreme weather, particularly heavy rainfall and heat waves.[1] Limpopo Province is already experiencing some changes to its climate and we should expect warmer wetter winters and hotter, drier summers in the future. Extreme weather, such as heat waves and very heavy rainfall is expected to become more frequent and intense. Very cold winters will still occur, though they will become less frequent. In addition to the multiple pressures from poverty, inadequate housing and poor access to services, this change in climate conditions will have an effect on Limpopo's economy, natural resources, and community livelihoods.

The Provincial Climate Change Strategy builds on the strong foundation of the Limpopo Development Plan and the Green Economy Plan and identifies a range of priorities for Limpopo and sets out how the province plan to work together in responding to climate change. The aims of this strategy are to:

i. articulate Limpopo's shared vision for responding to climate;
ii. recognise and build on the strengths of the province to deliver on this vision;
iii. profile how Limpopo will proactively and positively respond to climate change;
iv. identify and understand the gaps that exist in the approach to climate change;
v. develop a common agenda for collaboration and partnership working; and
vi. promote long term, integrated planning across different sectors and organisations to better manage our response to climate change in Limpopo.

The Strategy identifies measures needed to adapt to the climate change that is already happening and that which will happen whatever we do from now on as well as key areas where provincial actions can assist in both mitigating the impacts of climate change in energy, transport and resource efficiency. It takes a broad view and will be accompanied by supporting action plans. The Strategy will be reviewed and updated regularly in the light of changing circumstances and as prescribed in the Monitoring, Reporting and Evaluation section that concludes this strategy. Its success is subject to strong and improved governance as well as collaboration amongst all role players.

[1] Alex Kirby, "Three African Regions at High Risk from Climate Change," *ClimateCentral,* May 11, 2014. http://www.climatecentral.org/news/climate-hotspots-imperil-parts-of-africa-17417

Adaptation Measures

Adaptation is a process of identifying climate risks and opportunities, assessing the options to manage these risks and opportunities, and implementing the most sustainable actions to sustain and even improve our quality of life. In summary, the priority sectors for adaptation and the strategies are as follows:

Agriculture

i. Create a Climate Smart Agriculture programme to help develop or promote the use of specific seed or plant varieties in specific locations.

ii. Enhance ongoing efforts involving Conservation Agriculture.

iii. Initiate a dedicated climate change adaptation programme for cattle ranching / livestock rearing in the province.

iv. Fund and implement a comprehensive climate change awareness and skills-building programme within the province.

Livelihoods and Settlements – Rural and Urban

i. Devote resources to identifying and providing training on alternate sources of livelihood for different regions and communities within Limpopo.

ii. Create and strengthen support business development mechanisms for smallholder farmers.

iii. Redouble efforts to improve overall socio-economic security and wellbeing.

iv. Enhance efforts to reduce flood risk to rural and urban communities.

Ecosystems – Terrestrial and Aquatic

i. Develop a specialized climate change management programme to focus on protection of Limpopo's two main terrestrial ecosystems in the face of climate change.

ii. Identify and integrate specific climate-change related priorities and metrics when next revising the Limpopo Biodiversity Conservation Plan.

iii. Formally establish and draw resources to a scientific research project to better understand the loss of bird species-richness in the South African Limpopo Basin.

iv. Develop a focused climate change adaptation response plan and implementation programme targeting the province's wetlands and water pans.

Water Supply

i. Establish a cross-sectoral, inter-departmental governance framework to help integrate and mainstream climate change adaptation into all water related operations.

ii. Ensure that proposed water related infrastructure projects explicitly integrate climate change resilience into their planning and design stages.

iii. Raise performance and efficiency of water service delivery for domestic use, with aggressive quantitative targets.

iv. Strengthen existing Catchment Management efforts.

Human Health

i. Formally join, participate in, and leverage capacity and information from global climate change health networks and knowledge-sharing platforms.

ii. Secure, dedicate, and allocate substantial funding for better climate-related health surveillance and monitoring in the province and to carry out studies within Limpopo on health impacts of climate change.

iii. Fund and implement a comprehensive public health and climate change awareness and adaptive capacity building programme.

iv. Redouble efforts to improve overall socio-economic status and health indices.

Mitigation Measures

Mitigation are activities that reduce the amount of greenhouse gases emitted to the atmosphere and adaptation are actions initiatives and measures to reduce vulnerability of natural and human systems against actual or expected climate change effects. In summary, the priority sectors for mitigation and the strategies are as follows:

Renewable Energy and Energy Efficiency

i. Off grid solar energy program: This option provides for solar components that are absolutely dependent on solar energy supply. An off grid solar system refers to a component that does not need/have grid based energy back up, irrespective of whether it’s done in an area that has electricity supply or not. This could be in the form of components such as solar geysers, lighting systems, water pumps or even the whole household solar energy system. The latter only excludes stoves whereby gas stove is used.

ii. On grid solar energy program: This option provides for components that use both solar and grid energy supply. On grid solar system refers to components that have a grid based energy back up and therefore confined to areas that have grid electricity supply necessarily. This could be in the form of solar geysers, lighting systems, water pumps or the whole household solar energy system.

iii. Clean wind energy program: Wind borne electricity systems are less reliable for domestic or industrial use compared to solar energy systems and not recommended for domestic or industrial use.

iv. Green Building – reduce the amount of energy used in buildings by implementing measures to reduce energy demand and stimulate energy retrofits as well as renewable energy within private and public building should be implemented to reduce the carbon footprint within the province.

Waste Reduction and Resource Efficiency

i. Expand and strengthen provincial waste recycling programs and reduce the amount of waste sent to landfills: Major expanses of land and facilities are required to accommodate waste, and monitoring and mitigation are needed long after disposal. Actions that promote diversion of solid waste from landfills, such as recycling, composting and waste-to-energy initiatives, can reduce GHG emissions, prolong the life of landfills, and reduce disposal costs.

ii. Maintain programs for ensuring that solid waste is managed in a manner that protects health, safety, and the environment. Reducing waste generation and increasing reuse and recycling will reduce methane emissions as well as associated energy emissions from transportation and treatment.

iii. Develop and Implement programs and policies to encourage waste reduction and diversion by all sectors including residential and commercial.

iv. Develop and implement a sustainable integrated waste and energy plan for the province.

Transport and Land Use Management

i. Coordinate land use and site design decisions that promote walking, cycling, and taking public transportation.

ii. Reduce congestion and vehicle emissions by encouraging carpooling for commuters and car sharing for individuals making personal trips, purchasing more fuel efficient vehicles by residents and businesses, supporting improvements to national fuel efficiency standards, and reducing the carbon intensity of fuel sources.

iii. Promote smart mobility including efforts to improve traffic management, traffic lights synchronization and driving behaviors (such reduction in excessive idling)

iv. Encourage and support transport modal shifts and increase the use of transportation options such as public transit, cycling, walking, and carpooling

Industrial Emission Reduction through Cleaner Production and Resource Efficiency

i. Energy efficiency in commercial buildings sector. The strategies used to reduce emissions include energy-saving measures, such as reducing overall power consumption and high efficiency replacement equipment. Improving energy efficiency means changing energy consuming equipment or practices to reduce the energy used, without changing the ultimate service that the equipment or practice provides. Higher-than-average efficiency technologies exist for almost every use. Examples include installing efficient new heating systems in buildings, and energy efficiency improvements such as increased building insulation, and optimization systems for lights and heating/cooling, and more efficient windows.

ii. Implementation of sector-wide options resource and energy efficiency. Energy efficiency improvements for cross-cutting technologies, such as electric motor systems, can yield benefits across diverse sub-sectors. Other sector-wide mitigation options include the use of fuel switching, combined heat and power, renewable energy sources, more efficient electricity use, more efficient use of materials and materials recycling, and carbon capture and storage.

iii. Implementation of process-specific mitigation options. Certain mitigation opportunities come from improvements to specific processes and are not applicable across the entire sector. For energy-intensive industries, process improvements can reduce energy demand and, therefore, greenhouse gas emissions and energy costs. Other improvements can reduce emissions of non-CO_2 gases with high global warming potentials.

iv. Implementation standard Operating procedures improvement measures. A variety of mitigation opportunities can be achieved through improvements to standard operating procedures. These options can include making optimal use of currently available technologies, such as improving insulation and reducing air leaks in furnaces.

Agricultural Sector Emission Reduction

i. Cropland management practices including agronomy, nutrient management, tillage/residue management, water management, agro-forestry, Land cover (use) change.

ii. Grazing land management and pasture improvement practices to reduce GHG emissions and enhance removals including grazing intensity, increased productivity (including fertilization), nutrient management, fire management and Species introduction.

iii. Management of organic soils; methane emissions are usually suppressed after draining, but this effect is far outweighed by pronounced increases in N_2O and CO_2. Emissions on drained organic soils can be reduced to some extent by practices such as avoiding row crops and tubers, avoiding deep ploughing and maintaining a more shallow water table, but the most important mitigation practice, probably, is avoiding the drainage of these soils in the first place, or re-establishing a high water table where GHG emissions are still high

iv. Restoration of degraded lands; a large fraction of agricultural lands have been degraded by erosion, excessive disturbance, organic matter loss, salinization, acidification or other processes that curtail productivity. Often the carbon storage in these soils can be at least partly restored by practices that reclaim productivity including: re-vegetation (e.g. planting grasses); improving fertility by nutrient amendments; applying organic substrates such as manures, bio-solids and composts; reducing tillage and retaining crop residues; and conserving water. Where these practices involve higher nitrogen amendments, the benefits of carbon sequestration may be partly offset by higher N_2O emissions.

v. Livestock management. Livestock, predominantly ruminants such as cattle and sheep, are important sources of CH_4, accounting for approximately 18% of global anthropogenic emissions of this gas. The methane is produced primarily by enteric fermentation and voided by eructation). Practices for reducing CH_4 emissions from this source fall into three general categories: improved feeding practices, use of specific agents or dietary additives, and longer term management changes and animal breeding.

vi. Animal manure management. Methane emissions from manure stored in lagoons or tanks can be reduced by cooling or covering the sources, or by capturing the CH_4 emitted. The manures can also be digested anaerobically to maximize retrieval of CH_4 as an energy source. Storing and handling the manures in solid rather than liquid form can suppress CH_4 emissions, but may increase N_2O formation.

vii. Bioenergy production. Increasingly, agricultural crops and residues are seen as sources of feed-stocks for energy to displace fossil fuels. A wide range of materials have been proposed for use, including grain, crop residue, cellulosic crops and various tree species. These products can be burned directly, but often are processed further to generate liquid fuels such as ethanol or diesel fuel. These fuels release CO_2 when burned, but this CO_2 is of recent atmospheric origin (via photosynthesis) and displaces CO_2 which otherwise would have come from fossil carbon. The net benefit to atmospheric CO_2, however, depends on energy used in growing and processing the bioenergy feedstock.

Communication, Education and Public awareness

i. Develop and implement climate change communication, education and outreach plans to inform and engage all stakeholder in all sectors on efforts to reduce greenhouse gas emissions

ii. Develop public outreach plans by sector (i.e., transportation, commercial/industrial and residential) that promote and coordinate efforts to reduce greenhouse gas emissions.

iii. Seek opportunities to share information about the provincial climate change strategy and vision and identify opportunities for collaboration.

iv. Promote and support leading local businesses striving to meet energy and carbon reduction goals.

1. Introduction

Climate change is a reality and there is no longer any real debate over the fact that man-made emissions are the main cause. It is a multidimensional and complex challenge which poses serious environmental and socio-economic consequences. Its range of potential impacts represents one of humanity's most important threats facing future generations. Limpopo recognises its obligation to current and future generations in the face of climate change. As a result the province has taken a proactive step towards tackling climate change and responding to the challenges and opportunities this is causing by developing a provincial climate change strategy.

The purpose of developing a strategy for Limpopo is to agree on a practical approach to tackle climate change that supports Limpopo's objectives to boost Limpopo's economic development ambitions, protect Limpopo's citizens from severe weather, secure Limpopo's energy supply, improve the health and wellbeing and the quality of life for Limpopo's residents. This document outlines the strategic direction for Limpopo Province to address the challenges of climate change.

The Strategy addresses climate change through both mitigation and adaptation responses and identifies measures that can be implemented to offset the causes and effects of climate change. Mitigation are activities that reduce the amount of greenhouse gases emitted to the atmosphere and adaptation are actions initiatives and measures to reduce vulnerability of natural and human systems against actual or expected climate change effects.

The Strategy is underpinned by information which identifies the most vulnerable sectors and key measures for adapting to climate change, as well as the most carbon intensive sectors and key mitigation measures for reducing greenhouse gas emissions. It sets out Limpopo's vision for addressing climate change in the province, along with a set of underlying objectives.

Whilst developing the strategy, it became evident that addressing climate change has become increasingly embedded within numerous other climate change-related strategies and action plans. This strategy, therefore, becomes Limpopo's overarching document on climate change, referring to other relevant action plans where appropriate, to avoid duplication. This strategy, therefore, recognizes the importance of multi-stakeholder cooperation to ensure a concerted effort to combat climate change provincially.

2. Vision and Objectives

This strategy outlines the initial set of key objectives to be taken over the next four years and that can be adjusted on an ongoing basis as new ideas and solutions are developed. Specific actions will be outlined in a follow-up implementation plan. The strategy also reflects on government's strong commitment to maintaining a healthy economy and quality of life while addressing the challenge of climate change. The strategy sets the following vision and goals for the province:

Vision

A low carbon economy province that is resilient to impacts of a changing climate through concerted implementation of policies and programs that minimize greenhouse gas emissions, socio-economic threats and environmental risks while maximizing the benefits from opportunities which may arise from climate change.

Mission

To enhance Limpopo's current and future development by strengthening its adaptive capacity and building resilience of the society and ecosystems while reducing greenhouse gas emissions from all source sectors.

Goals

Through this strategy the province commits to address the following goals:

i. raise the profile and understanding of how the province can proactively and positively respond to climate change;
ii. develop a common climate change agenda for Limpopo, articulate a shared vision and build on the strengths of the province to deliver on this vision through collaboration and partnerships;
iii. slow the increase of GHG emissions by implementing a range of mitigation programs such as increased energy efficiency in all sectors, development of renewable energy sources and sustainable use of natural resources;
iv. Improve public awareness and preparedness for future climate change throughout the province; and
v. promote long term, integrated planning across different sectors and organisations to better manage provincial response to climate change in Limpopo.

3. Overarching Policy and Legislative Context

This section highlights an overview of the policy context in respect of addressing climate change at international, national and provincial levels. Both aspects of climate change are considered separately; adapting to the future effects of climate change and mitigating greenhouse gas emissions.

3.1. International legal policy framework

The United Nations Framework Convention on Climate Change (the "Climate Change Convention") commits all Parties to formulate, implement, publish and update adaptation measures, as well as to cooperate on adaptation. Countries have submitted information on their adaptation plans in their 5th National Communication to the United Nations Framework Convention on Climate Change[4]. These Parties have already highlighted the most important elements that might be part of an enhanced multilateral response to climate change up to and beyond 2012. Climate change mitigation and adaptation two of the five key building blocks (shared vision, mitigation, adaptation, finance and technology) of a future climate change deal.

The importance of adaptation was reiterated in the Copenhagen Accord, which emphasizes that enhanced action and international cooperation on adaptation is urgently required to ensure the implementation of the Convention by enabling and supporting the implementation of adaptation actions aimed at reducing vulnerability and building resilience in developing countries, especially in those that are particularly vulnerable, especially least developed countries, small island developing States and Africa.

Under the negotiating process towards Cancun, countries made progress in defining a comprehensive adaptation framework, which will enable all countries to share knowledge and lessons learned from adaptation and developing countries to develop and implement adaptation measures supported through scaled-up financial support, technology and capacity-building. The final elements of the framework remain to be agreed through the negotiations.

Parties have emphasized that adaptation (the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities) and mitigation (human intervention to reduce the sources of greenhouse gases[5]) need to be accorded the same level of importance. Adaptation does not replace mitigation of greenhouse gas emissions. On the contrary, both adaptation and mitigation need to be pursued in parallel during the same period of time, thus complementing each other, and they need to be implemented through sufficient financing and appropriate technology[6].

In December 2015, the Paris Agreement adopted, after four years since the launch of the process to develop the legal instrument under the Ad hoc Working Group on the Durban Platform for Enhanced Action (ADP). The Agreement cover all the crucial areas identified as essential including mitigation, a transparency system and global stocktake, adaptation, loss and damage as well as support including finance, for nations to build clean, resilient futures. It brings all nations into a common cause based on their historic, current and future responsibilities and reaffirms the goal of limiting global temperature increase well below 2^{o}C, while urging efforts to limit the increase to 1.5oC above pre-industrial levels. The Paris Agreement establishes a global goal of "enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change. It requires all parties as appropriate to plan and implement adaptation efforts (priorities) and to report on their adaptation plans and/or support needs. Developing countries will receive increased support for adaptation actions and the adequacy and effectiveness of adaptation support will be assessed in the global stocktake to be undertaken every five years.

With respect to countries' individual mitigation efforts, the agreement prescribes binding procedural commitments by all parties to make "nationally determined contributions" (NDCs), and to pursue domestic measures aimed at achieving them as well as commit all countries to report regularly on their emissions and "progress made in implementing and achieving" their NDCs, to undergo international review and to submit new NDCs every five years, with the clear expectation that they will "represent a progression" beyond previous ones. The core mitigation commitments are common to all parties, but there is some differentiation in the expectations set: developed countries "should" undertake absolute economy-wide reduction targets, while developing countries "are encouraged" to move toward economy-wide targets over time. In addition, developing countries are to receive support to implement their commitments. NDCs will be recorded in a public registry maintained by the UNFCCC secretariat, rather than in an annex to the agreement, as some countries had proposed. The agreement also reaffirms the goal of keeping average warming below 2 degrees Celsius, while also urging parties to "pursue efforts" to limit it to 1.5 degrees, a top priority for developing countries highly vulnerable to climate impacts.

3.2. National Policy and Legislative Framework

3.2.1. Constitution of the Republic of South Africa

The South African Constitution (Act 108 0f 1996) provides and overall framework governing the development and implementation of climate change adaptation and mitigation strategies. The Constitution's environmental clause in the Bill of Rights section 24 provides as follows:

"Everyone has the right –

a) To an environment which is not harmful to their health or well-being;

b) To have the environment protected for the benefit of present and future generations through reasonable legislative and other measures that:

i. prevent pollution and ecological degradation;

ii. promote conservation; and

iii. secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development."

Apart from the Bill of Rights, it is important to understand the administrative framework which is established in the Constitution. The National Government and the Provincial Government are both entitled to legislate on matters stipulated in Schedule 4 to the Constitution. Both spheres of Government have legislative competence over areas that will impact on management in the natural/physical interface, like disaster management, environment and natural resources management, agricultural development and spatial development planning.

3.2.2. The National Development Plan

The National Development Plan (NDP), developed by the National Planning Commission, aims to eliminate poverty and reduce inequality by 2030. The NDP highlights climate change as one of the key responses and acknowledges South Africa's role as a contributor to GHG emissions. In addition, it notes that South Africa is particularly vulnerable to the effects of climate change on health, livelihoods, water and food with a disproportionate impact on the poor, especially women and children. It sets the long-term vision for the country that will need to be implemented by all spheres of government and sectors of society in order to achieve the goals set forth in the document.

Chapter 5: Environmental Sustainability and Resilience, focuses on ensuring environmental sustainability and an equitable transition to a lower carbon economy and includes a number of objectives and actions which are specifically linked to climate change. These include:

- Achieve the peak, plateau and decline trajectory for GHG emission, with the peak being reached around 2025;
- By 2030, an economy-wide carbon price should be entrenched;
- Carbon price, building standards, vehicle emissions, standards and municipal regulations to achieve scale in stimulating renewable energy, waste recycling and in retrofitting buildings;

- Carbon pricing mechanisms, supported by a wider suite of mitigation policy instruments to drive energy efficiency;
- Zero emission building standards by 2030;
- All new buildings to meet the energy efficiency criteria set out in SANS 204;
- Absolute reductions in the total volume of waste disposed to landfill each year;
- At least 20 000 MW of renewable energy should be contracted by 2030;
- Improved disaster preparedness for extreme climate events;
- Increased investment in new agricultural technologies, research and the development of adaptation strategies for the protection of rural livelihoods and expansion of commercial agriculture;
- Channel public investment into research, new agricultural technologies for commercial farming as well as for the development of adaptation strategies and support services for small-scale and rural farmers.
- An independent Climate Change Centre in partnership with academia and other appropriate institutions, to be established by government to support the actions of government, business and civil society;
- Put in place a regulatory framework for land use, to ensure conservation and restoration of protected areas;

There are also strong climate change links with other chapters in the National Development Plan, including Chapter 3: Economy and Employment, which includes a focus on the green economy, transition to a low carbon economy and society, and fostering motivation in green product and service development; Chapter 4: Economy Infrastructure, which includes the efficient and effective implementation of the environmental impact management governance system for new developments and the implementation of the Strategic Infrastructure Projects (SIP's) proactive authorisation process. Chapter 6 focuses on the promotion of an integrated and inclusive rural economy and Chapter 8: Transforming Human Settlements focuses on green cities and sustainable development.

3.2.3. National Climate Change Response Policy

The primary policy approach in respect of climate change response is framed within the National Climate Change Response (NCCR) White Paper (2011). This document outlines strategic priorities, provides direction for action and delineates responsibilities for the different spheres of government. The NCCR, presents the South African Government's vision for an effective climate change response and the long-term, just transition to a climate-resilient and lower-carbon economy and society. South Africa's response to climate change has two objectives:

(i) To effectively manage the inevitable climate change impacts through interventions that build and sustain South Africa's social, economic and environmental resilience and emergency response capacity; and

(ii) To make a fair contribution to the global effort to stabilise greenhouse gas (GHG) concentrations in the atmosphere at a level that avoids dangerous anthropogenic interference with the climate system within a timeframe that enables economic, social and environmental development to proceed in a sustainable manner.

The NCCR focuses on three key Aspects; adaptation, mitigation, and mainstreaming sustainable and 'climate-resilient' development. In addition, the NCCR highlights eight near-term Priority Flagship Programmes that will be undertaken in the immediate future. These include:

- The Climate Change Response Public Works Flagship Programme;
- The Water Conservation Flagship Programme;
- The Renewable Energy Flagship Programme;
- The Energy Efficiency and Energy Demand Flagship Programme;
- The Transport Flagship Programme;
- The Waste Management Flagship Programme;
- The Carbon Capture and Sequestration Flagship Programme; and
- The Adaptation Research Flagship Programme.

The NCCR includes the development of a Monitoring and Evaluation System that will serve as the national tracking and reporting structure for South African climate change responses.

3.3. Provincial Policy and Legislative Framework

3.3.1. Limpopo Development Plan

The Limpopo Development Plan LDP 2015 – 2019 is the overarching strategy for Limpopo Province. It is an overarching operational medium-term strategy for the province, focused towards achieving the provincial vision. The main drive of the LDP is to reduce poverty, unemployment levels and inequality through sustainable development and transformation as a means of growing the economy the LDP also intends to curb the triple challenges, (viz., poverty, inequality and unemployment) that have adversely affected the province and the country at large. Furthermore, the LDP emphasizes enhancing economic growth with focus on mining, manufacturing, agriculture and tourism as well as empowering SMMEs and Cooperatives. The objectives of the LDP are to:

- Create decent employment through inclusive economic growth and sustainable livelihoods
- Improve the quality of life of citizens
- Prioritize social protection and social investment
- Promote vibrant and equitable sustainable urban and rural communities
- Raise the effectiveness and efficiency of developmental public service
- Ensure sustainable development

3.3.2. Limpopo Green Economy Plan

The Limpopo Provincial government commissioned a provincial green economy plan (Limpopo Green Economy Plan) which aims to increasing employment and grow the economy through the creation of green jobs. The plan envisages a green economy in agriculture, construction, manufacturing, infrastructure, science and technology, and services including activities that help to protect and restore ecosystems and biodiversity; reduce energy, materials, and water consumption through high efficiency and avoidance strategies; de-carbonize the economy; and minimize or altogether avoid degeneration of all forms of waste and pollution. The principal objective of Limpopo Green Economy

Plan is to support and direct the re-orientation and growth of the Limpopo's economy to become increasingly competitive and resilient by generating green jobs, improving environmental quality, creating enabling conditions for green growth, changing behavioural and production patterns, and building a new economic/environmental paradigm for Limpopo. These will be implemented through specified initiatives in the key focus areas such as sustainable production and consumption, sustainable waste management practices, clean energy and energy efficiency, resource conservation and management, agriculture, food production and forestry, green buildings and the built environment, sustainable transport and infrastructure and green municipalities.

3.3.3. Limpopo Conservation Plan

The Limpopo Conservation Plan (CPlan) was updated in 2012. Version 2 of the C Plan was made available in 2013. The primary objective of the project was to produce a revised conservation plan for Limpopo Province that conformed to the Bioregional Planning guidelines published by SANBI in 2009 (Limpopo CPLan V2, 2013). The previous Limpopo Conservation Plan (LCPv1) was completely revised by developing and executing quantitative systematic spatial biodiversity planning methodologies that: addressed the deficiencies of the previous provincial plan; has taken into account the most up-to-date spatial data and institutional and expert knowledge; aligned the methods and terminology of the plan with the national guidelines for the development of bioregional plans; has taken into account existing spatial biodiversity planning products; and, involved skills transfer through working with LEDET staff on the development of the CBA map and GAP assessment (Limpopo CPlan V2, 2013). The systematic conservation planning process resulted in 40% of the province being identified as Critical Biodiversity Areas (CBAs) and 22% Ecological Support Areas (ESAs). The table below provide a breakdown of CBA and ESA areas identified within the Limpopo province. According to the Limpopo Conservation Plan V2 (2013), eight of the 56 vegetation types found in Limpopo Province are threatened; one of these is considered critically endangered (CR), one is considered endangered (EN), and six are considered vulnerable (VU).

3.4. Limpopo Province in context

Limpopo is South Africa's northernmost province, lying within the great curve of the Limpopo River. The province borders the countries of Botswana to the west, Zimbabwe to the north and Mozambique to the east. With a total area of 125 754 square kilometres accounting for up 10.3% of South Africa's land area and being with a population of 5 518 00 (10.4% of SA population) people in 2013, Limpopo is the fifth-largest of the country's nine provinces in both surface area and population. It is divided into five district municipalities (Capricorn, Mopani, Sekhukhune, Vhembe and Waterberg) which are further subdivided into 25 local municipalities (Figure 1). The northern half of Kruger National Park lies in the east of Limpopo.

Amongst the key urban centres is Polokwane, the provincial Capital, located in the middle of the province. Further north is Modimolle, the hub of the local table-grape industry set near the Waterberg mountain range; Makhado at the foot of the Soutpansberg mountains; and Musina, well known for baobab trees. Other important Limpopo towns include the major mining centres of Tubatse, Phalaborwa and Thabazimbi, as well as Tzaneen, which produces tea, forestry products and tropical fruit. Bela- Bela, with its popular mineral water baths, is near the southern border.

The province is characterised by four climatic regions, the subtropical plateau which is a flat elevated interior area that is hot and dry with winter rain, the moderate eastern plateau with warm to hot and rainy summers and cold dry winters, the escarpment region with colder weather because of the altitude and rain all year around; and the subtropical Lowveld region, of hot-rainy summers and warm-dry winters, also known as the South African Bushveld (Limpopo Department of Agriculture, 2008; Tshiala et al, 2011:14[2]).

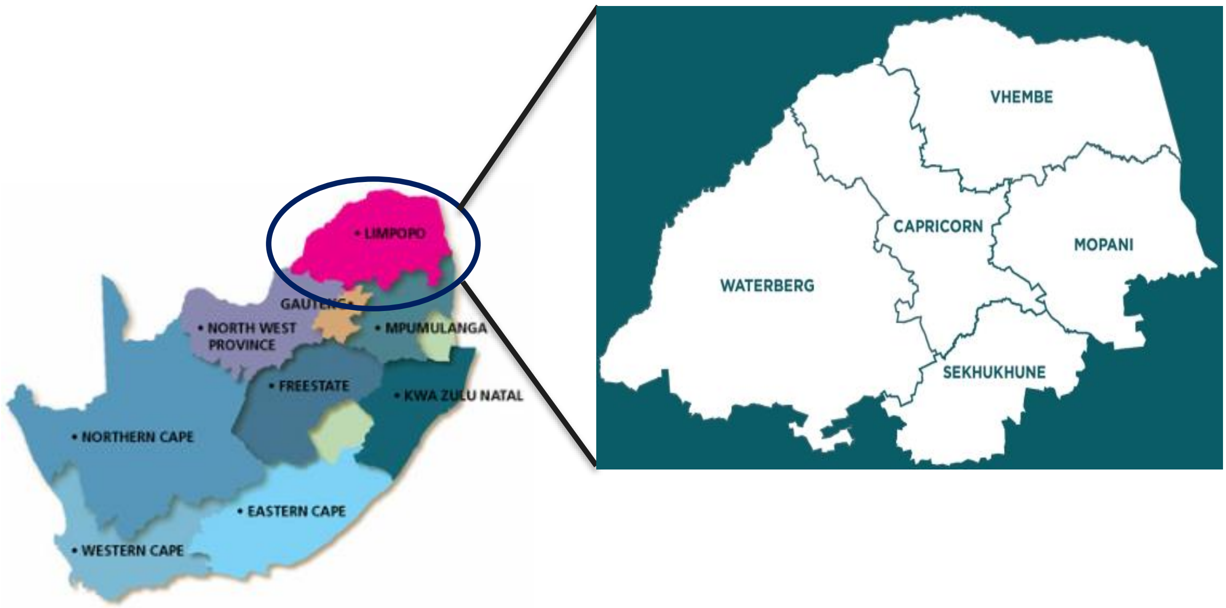


Figure 1: Limpopo Province in context

The province lies in the savanna biome, an area of mixed grassland and trees known as bushveld. A summer-rainfall region, the northern and eastern areas are subtropical with hot and humid summers and mist in the mountain areas. Winter is mild and mostly frost-free. Limpopo has a thriving tourism industry. In addition to the Kruger National Park, there are 54 provincial reserves and several luxury private game reserves. It is also home to the Mapungubwe Cultural Landscape, one of South Africa's eight World Heritage sites. It is characterised by extreme levels of poverty and is generally poorly developed. It also one of the poorest regions of South Africa with a big gap between poor and rich residence, especially in rural areas [8]. The province also suffers from a low skills base which translates into very limited socio-economic development opportunities. As a result, there is heavy reliance on subsistence agriculture on land portions that are mostly of marginal agricultural productivity. Nevertheless, the province has shown great improvements in the economy and standard of living, exporting primary products and importing manufactured goods and services.

The average annual real economic growth rate for Limpopo from 2003 to 2013 was 2.7% and the real annual economic growth rate for 2013 compared with 2012 was 2.4%, ranked number three amongst the nine provinces, after Gauteng at 2.6% and Northwest at 2.5%. Limpopo's economic growth rate in 2013 was attributable to a contribution of mining at 26.0%; government services at 17.6%; whole sale, retail and motor trade, catering and accommodation at 13.7%; and finance, real estate and business

[2] Tshiala, M.F et al 2011 Analysis of Temperature Trends over Limpopo Province, South Africa. Journal of Geography and Geology Vol. 3, No. 1.

services at 11.7% (Statistics South Africa, 2014[3]). The growth rate was however dampened by declining contributions of 2.2% in agriculture, forestry and fishing; 2.3% in manufacturing and 23.0% in construction (ibid).

It is evident that mining is the main driver of Limpopo's economic activity. The rich mineral deposits of the province include platinum group metals, iron ore, chromium high- and middle-grade coking coal, diamonds, antimony, phosphate and copper, as well as mineral reserves such as gold, emeralds, scheelite, magnetite, vermiculite, silicon and mica. Base commodities such as black granite, corundum and feldspar are also found in the province. Mining contributes to more than a fifth of the provincial economy. The province mainly exports primary products and imports manufactured goods and services. Along with Mining, agriculture and tourism have been identified in the Limpopo Development Plan (2015) as important sectors to stimulate employment creation and economic growth for Limpopo Province.

In the agriculture sector, the province is endowed with abundant agricultural resources and it is one of the country's prime agricultural regions noted for the production of fruits and vegetables, cereals, tea, and sugar. The varied climates allow Limpopo to produce a wide variety of agricultural produce (Oni SA, et. Al, undated[4]). Sunflowers, cotton, maize and peanuts are cultivated in the Bela-Bela and Modimolle areas. Modimolle is also known for its table-grape crops. Tropical fruit, such as bananas, litchis, pineapples, mangoes and pawpaws, as well as a variety of nuts, are grown in the Tzaneen and Makhado areas. Tzaneen is also at the centre of extensive tea and coffee plantations. In addition to several thousand tonnes of potatoes, Limpopo produces the majority of South Africa's mangoes, papayas, avocados, citrus and tomatoes. Extensive forestry plantations are also found in Limpopo, including hardwood for furniture manufacture. In addition to commercial agriculture, subsistence farming is the mainstay of a large section of the rural population.

This Province is mainly a cattle production area and controlled hunting is often combined with ranching. About 80% of South Africa's hunting industry is found in Limpopo. The growth in the agriculture sector has demonstrated high volatility, peaking at 24.1% in 1998 and dropping to a low negative 6.9% in 2006. The sector further experienced negative growth rates in 2010 and 2011 with 1.4% and 0.6% respectively. This is a concern for the province as agriculture in the one of the strategic pillars and the biggest employer in the provincial economy (LEDET, 2013:15). The institutional infrastructure of agriculture differs in quality, availability and accessibility between commercial and subsistence farms and farmers within the Province (Gbetibouo and Ringler, 2009:7; Coetzee and Van Zyl 1992). Moreover, Limpopo's agriculture is highly sensitive owing to densely populated rural areas, large numbers of small-scale farmers, high dependency on rainfed agriculture and high land degradation.

With respect to tourism, Limpopo has a thriving tourism industry. In addition to the well-known Kruger National Park, there are 54 provincial reserves and several luxury private game reserves. It is also home to the Mapungubwe Cultural Landscape, one of South Africa's eight World Heritage sites. The potential effects of climate change on these sectors are well known and have been publicised in numerous reports that have outlined the effects of climate change. It is therefore critical that suitable

[3] Statistics South Africa, Statistical Release P0441, Gross Domestic Product Annual Estimates 2004 – 2013, Third Quarter 2014
[4] Oni SA, Nesamvuni AE, Odhiambo JJO, and Dagada MC; Study of Agricultural Industry in the Limpopo Province: Executive Summary, Part I

adaptation measures or mitigation strategies for these sectors as well as others are instituted urgently to offset the effects of climate change.

3.5. Anticipated climate change effects for the province

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), indicates that global temperatures rose by 0.74^{0}C over the past 100 years, and it is projected that the temperature will rise by 1.1 – 6.4^{0}C by the end of this century. The report also points out that the impacts of climate change are widespread around the world and cut across many critical sectors of society including ecosystems and their services, human health, human security, extreme climate conditions, the diminishing of glaciers and the sea level rise that causes atolls and low lying areas to submerge under water. The report further outlines Africa is the most vulnerable continent, a situation that is aggravated by the interaction of 'multiple stresses', including high dependence on rain-fed agriculture, widespread poverty and weak adaptive capacity. Some of the observed impacts in recent years, show that in Africa will experience extreme weather and climate events including droughts and floods which will have significant impacts on economic sectors, natural resources, ecosystems, livelihoods, and human health.

The report revealed that southern Africa will suffer a decrease in water resources due to climate change. Drought-affected areas are projected to increase in extent, with the potential for adverse impacts on multiple sectors such as agriculture, water supply, energy production and health. Regionally, large increases in irrigation water demand as a result of climate changes are projected. The beneficial impacts of increased annual runoff in some areas are likely to be tempered by negative effects of increased precipitation variability and seasonal runoff shifts on water supply, water quality and flood risk. Climate change is already damaging crops and disrupting business, and costing governments billions they could be spending on infrastructure investment, social services, and economic development.

South Africa is already experiencing the impacts of climate change, and is becoming increasingly aware of future impacts that it must prepare for.[5] The country is located in one of the three regions of the African continent that is most likely to suffer significant adverse impacts from climate change.[6] The country will experience progressively warmer and drier summers, wetter and milder winters and more frequent extreme weather, particularly heavy rainfall and heat waves. All of South Africa's provinces, including Limpopo, are likely to witness changes brought about by future climate change.

The Long Term Adaptation Scenarios (LTAS) suggests that the region within which Limpopo province is located could face a potential increase in temperatures by as much as 2°C by 2035, by 1-2°C between 2040 and 2060 (or even 2-5°C in the high-end scenarios), and by 3-6°C between 2080 and 2100 (or as much as 4-7°C in the high-end scenarios). LTAS projects decreased rainfall over Limpopo in the long term[7] while other studies suggest that there may be future increases in rainfall in the region, attesting to the uncertainty in model projections for this region of Southern Africa within the existing body of

[5] DEA, "South Africa's Second National Communication Under the United Nations Framework Convention on Climate Change," *UNFCCC,* 2011. http://unfccc.int/resource/docs/natc/zafnc02.pdf
[6] Alex Kirby, "Three African Regions at High Risk from Climate Change," *ClimateCentral,* May 11, 2014. http://www.climatecentral.org/news/climate-hotspots-imperil-parts-of-africa-17417
[7] Long Term Adaptation Scenarios, "Climate Trends and Scenarios," 2013. http://www.sanbi.org/sites/default/files/documents/documents/ltasclimate-trends-and-scenarios-tech-report2013low-res.pdf

knowledge. However, what emerges out of such uncertainty is that the region is likely to experience greater variability in rainfall, and will almost certainly witness an increase in evaporation rates,[8] implying a drier future even in the presence of greater rainfall and heavy rainfall events.[9].

Limpopo Province would therefore experience regular droughts and heat intensity, water shortages, spread of diseases with adverse effects on the economy, natural resources, infrastructure, human health and community livelihoods. Water shortages are already a key feature in the drier Limpopo Province and the situation is going to become even more severe as a result of climate change. Important water use sectors such as agriculture and electricity generation (i.e. the energy sector) will face severe effects from climate change. A detailed climate change vulnerability assessment for Limpopo revealed that sectors such as human health, agriculture, plant and animal biodiversity, water resources, and water and road infrastructure, livelihoods as areas showing the highest vulnerability to climate change mainly because the Province comprises predominantly rural areas that are dependent on rain-fed agriculture with a low economic development, low levels of human and physical capital, poor infrastructure standing, and therefore very low adaptive capacity.

There is therefore an urgent need to tackle climate change through robust and holistic approaches that would effectively address the challenges of climate change. This strategy aims to ensure that Limpopo Province responds to climate change and the associated adverse impacts and that the Province is well positioned to take advantage of the opportunities associated with our changing climate.

3.6. Responding to climate change: adaptation and mitigation

Responses to climate change are generally of two forms, adapting our behaviour to offset the effects of climate change, or dealing with the effects of climate change by reducing the levels of greenhouse emissions. In recognition of the need to be better prepared for such climate change impacts and uncertainty, Limpopo province has taken laudable steps towards building its climate change resilience and low carbon economy that prioritises the sustainable use of natural resources while overcoming the development challenges faced by the majority of Limpopo citizens.

A key initial step was the development of the Limpopo Green Economy Plan.[10] This strategy builds on the strong foundation of the Green Economy Plan by assessing climate change risks and vulnerability of major sectors, by profiling provincial level greenhouse gas emissions from various sectors and thereafter by identifying high-level strategies to reduce carbon footprint and vulnerabilities of various sectors by strengthening the ability to respond and cope well, (i.e. reducing vulnerabilities, enhancing adaptive capacity and building resilience. This strategy captures a set of initial mitigation and adaptation strategies for each of the key sectors in Limpopo that are highly carbon intensive (based on the greenhouse gas emissions profiles) or that exhibit high climate change vulnerability (based on the findings of a vulnerability assessment) or sectors that are critical to the province's economy.

[8] Department of Science and Technology, "South African Risk and Vulnerability Atlas," 2010 http://www.rvatlas.org/download/sarva_atlas.pdf

[9] Long Term Adaptation Scenarios, "Agriculture and Forestry," 2013 http://www.sanbi.org/sites/default/files/documents/documents/ltasagriculture-and-forestry-tech-report2013high-res.pdf

[10] LEDET, Provincial Government of Limpopo, "Limpopo Green Economy Plan: Including Provincial Climate Change Response," June 2013. https://www.environment.gov.za/sites/default/files/docs/limpopogreen_economyplan.pdf

The identification of sectors and overall project approach and methodology were validated with stakeholders and experts in a workshop in Limpopo province in March 2015, and the strategies were presented to and reformulated by stakeholders in a second such workshop in the province in May 2015. Thus, stakeholders within the province endorsed (and in many cases proposed) the strategies enumerated here.

4. Climate Change Mitigation

Mitigation are activities that reduce the amount of greenhouse gases emitted to the atmosphere. Human activities such as industrial processes, fossil fuel combustion, and changes in land use have altered the balance of greenhouse gases in the Earth's atmosphere. The Earth's climate and weather patterns have responded to such changes, with increases in the frequency and intensity of extreme weather events, loss of biodiversity, impacts to human health, disruption of ecosystems, and other effects. Mitigation measures are generally those activities that target the reduction of the agents that cause climate change. In that sense, mitigation measures focus solely on reducing the emissions of greenhouse gases that cause climate change.

Limpopo recognizes the importance of doing its part to mitigate these serious consequences of climate change. This inventory reports annual levels of GHG emissions attributable to all activities occurring within the Province with 2013 as the base year. By estimating and analyzing GHG emissions, the Province will be able to track the progress it is making toward achieving greenhouse gas emissions reduction measures. This inventory was developed at provincial level and does not disaggregate emissions per district. Up to date there is not an official GHG inventory published for the Limpopo Province; although the declaration of GHG as priority pollutants[11], the national pollution prevention plans regulations[12] and the future implementation of a national reporting system[13] of emissions is expected to facilitate the task in the middle-long term. The current GHG inventory should be viewed as a first level emission inventory and a comprehensive greenhouse gas emission inventory for the province must be developed in future.

4.1. Overall Approach to Mitigation

The GHG inventory was conducted in accordance with the 2006 Intergovernmental Panel on Climate Change (IPCC) guidelines. The principal goal of compiling an emission inventory presented in this strategy is to provide a baseline and general understanding of Limpopo's current GHG emissions. The inventory has been prepared to provide sound, science based and comparable reporting of GHG sources in Limpopo. The current GHG inventory is a first level account of emission releases from anthropogenic sources for which data was readily available. The inventory report is structured using the categorical breakdown of GHG sources grouped into energy and waste. Greenhouse gas emission inventories in this report were estimated based on the methods outlined in the GHG protocol which

[11] Draft Regulations published for public comment on 08 January 2016: Declaration of greenhouse gases as priority pollutants (GG 39578, Notice 6, 8 January 2016)

[12] Draft Regulations published for public comment on 08 January 2016: Declaration of greenhouse gases as priority pollutants (GG 39578, Notice 5, 8 January 2016)

[13] Draft Regulations published for public comment on 08 January 2016: National greenhouse gases emission reporting regulations (GG 38857, Notice 541, 8 June 2015)

provides an international standard for accounting and reporting GHG emissions. The report does not take into account GHG sinks.

The 2006 IPCC guidelines offer three approaches for estimating emissions in terms of the species which are emitted from fossil fuel combustion. During the combustion process, most of the carbon is immediately emitted as CO_2. However, some carbon is released as carbon monoxide (CO), methane (CH_4) or non-methane volatile organic compounds (NMVOCs). Most of the carbon emitted as these non-CO_2 species eventually oxidizes to CO_2 in the atmosphere. In the case of fuel combustion, the emissions of these non-CO_2 gases contain very small amounts of carbon compared to the CO_2 estimate and at Tier 1, it is often more accurate to base the CO_2 estimate on the total carbon in the fuel. A tier represents a level of complexity in calculating the emission inventory of a category. Higher tiers are usually more accurate, but also more demanding in terms of data availability and in handling of methodological complexity. There are three tiers presented in the 2006 IPCC Guidelines for estimating emissions from fossil fuel combustion for electricity generation. In these tiers, fuel consumption and emission factors are considered as follows[14]

i. Tier 1: Tier 1 is a fuel-based method to estimate GHG emissions. In this tier, the quantities of consumed fuel and average emission factors for all relevant direct greenhouse gases are used for GHG analysis. The Tier 1 emission factors are available in IPCC guidelines. Table 2 shows default emission factors for three fuels.

ii. Tier 2: In Tier 2, similar to Tier 1, the quantities of consumed fuel from fuel statistics are used to estimate GHG emissions. But instead of the Tier 1 default emission factors, country specific emission factors are used.

iii. Tier 3: Tier 1 and 2 approaches of estimating GHG emissions necessitate using an average emission factors, either default emission factors in Tier 1 or country specific emission factors in Tier 2. In reality, GHG emissions depend upon the fuel type, combustion technology, operating conditions, control technology, quality of maintenance and age of the equipment. In Tier 3 approach, these parameters are taken into account by using different emission factors for each case.

All these tiers use the amount of fuel combusted as the activity data. In the energy sector, the activity data are typically the fuel consumption to generate electricity. These data are sufficient for the Tier 1 analysis. In higher tier approaches, additional data are required on fuel characteristics and power generation technologies.

The Global Protocol for Community scale Greenhouse Gas Emission Inventories (World Resource Institute C40 and ICLEI, 2014)[15] is a first globally tested accounting standard for an urban GHG inventory (GPC Protocol for short). In addition the International Local Government GHG emission Analysis Protocol which is a predecessor to the GPC protocol was released by ICLEI in 2009. Although these emission inventory methods targets the urban and local government level, they can also be applied to other administrative regions below the national level. Activities taking place within a sub-

[14] (IPCC) The Intergovernmental Panel on Climate Change (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

[15] WRI, ICLEI, C40. (2014). Global Protocol for Community-Scale Greenhouse Gas Emission Inventories

national region can generate GHG emissions that occur inside the boundaries of the region as well as outside the region. To distinguish among them, the GPC groups emissions into three categories based on where they occur: Scope 1, Scope 2 or Scope 3 emissions.

Limpopo's GHG inventory was conducted in accordance to the approved principles and standards of both the International Local Government GHG emission Analysis Protocol (IEAP) and the Global Protocol for Community scale Greenhouse Gas Emission Inventories (GPC). In this report scope 1 and scope 2 emissions have been considered. Scope 1 emissions are all direct emissions sources located within the geographical boundary of Limpopo province, Scope 2 emissions are indirect emissions that result from sources located within the geographical boundary of Limpopo province.

Table 1: Scope 1 emissions sources categories

Scope 1 Emissions	**Source Category**	
Scope 1 All direct emissions sources located within Limpopo's boundary:	Consumption Based Emission Sources	Fossil Fuel - Residential
		Fossil Fuel - Industrial
		Fossil Fuel - Transport
		Fossil Fuel - Agriculture
		Fossil Fuel - General
	Generation Based Emission Source	Matimba Power Station
Scope 2 Emission Sources	**Source Category**	
Scope 2 Emissions: Indirect emissions limited to electricity consumption within the Province, but the associated emissions occur outside of the Limpopo's boundary	Electricity - Residential	
	Fossil – Industrial	
	Electricity - Transport	
	Electricity – Agriculture	
	Electricity – General	

4.2. Global Warming Potentials of GHGs

There are three major gases that are influenced by human activities and that are of interest with respect to greenhouse gas emissions, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The concept of "global warming potential" (GWP or CO_2e) has been developed to enable comparison of the ability of different GHGs to trap heat in the atmosphere (radiative forcing)[16]. By definition, the

[16] The term "radiative forcing" refers to the amount of heat-trapping potential for a GHG, measured in units of power per unit of area (watts per metre squared).

GWP from the release of 1 kg of CO2 is one, with the GWP of other GHGs stated relative to CO2. The GWP of a GHG accounts for both the immediate radiative forcing due to an increase in the concentration of the gas in the atmosphere, and the lifetime of the gas. The following summary table lists the "100-Year GWP" for the major gases and groups of gases (Table 2).

Table 2: Global Warming Potentials

Greenhouse Gas	Global Warming Potential
CO_2	1
CH_4	21
N_2O	310

Greenhouse gas emissions associated with provincial sources and included in the provincial emission inventory are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). In accordance with the GHG protocol, emission volumes were estimated and expressed in values of carbon dioxide equivalent (CO_2-e) (IPCC, 2006). These values are derived by applying a Global Warming Potential (GWP) factor to each type of GHG.

4.3. Emission Factors

GHG emissions are typically estimated using emission factors, metrics that relate quantity of emissions released to unit levels of activity data. Emission factors, also known as conversion factors, are generally expressed in kilograms of carbon dioxide equivalent (Kg CO_2 e). Carbon dioxide equivalent (CO_2 e) is used since most forms of energy emit more than one GHG. To calculate the CO_2 e the amount of the various GHGs are multiplied by their Global Warming Potential relative to carbon dioxide and then summed. Emission factors are determined using mass balance, fixed chemical equations or other relation-ships under average conditions. The factors can be averaged across various geographical ranges – nationally, provincially or even at a facility-specific level.

In some countries, government agencies publish country specific emission factors to assist with greenhouse gas reporting. Unfortunately since South Africa does not yet have its own publically available source of country specific emission factors. As a result, the United Kingdom's (UK) Department for Environment, Food and Rural Affairs (DEFRA) emission factors are often used instead.

For some energy sources a factor calculated for the UK will be reasonably similar to the result for South Africa (for instance the factor for petrol with a similar blend), however some will be completely different (for instance the factor for electricity varies from country to country since all countries generate electricity differently). In order to compare energy sources, units have been converted to joules – the standard energy unit. The conversion factors have been drawn from annexure B to the DOE's draft 2012 Integrated Energy Planning Report and are indicated in Table 3 below.

Table 3: Energy conversion factors, South Africa

Energy carrier	Energy	Unit	Energy	Unit	Density (kg/ℓ)	MJ/kg
Aviation gas	33,9	MJ/ℓ	0,0339	GJ/ℓ	0,73	46,4
Coal (bituminous)	24,3	MJ/kg	0,0243	GJ/kg	-	-
Diesel	38,1	MJ/ℓ	0,0381	GJ/ℓ	0,84	45,4
Electricity	3,6	MJ/kWh	0,0036	GJ/kWh	-	-
Heavy fuel oil	41,6	MJ/ℓ	0,0416	GJ/ℓ	0,98	42,3
Jet fuel	34,3	MJ/ℓ	0,0343	GJ/ℓ	0,79	43,3
Liquid petroleum gas	26,7	MJ/ℓ	0,0267	GJ/ℓ	0,54	49,4
Natural gas	41	MJ/m^3	0,0410	GJ/m^3		
Paraffin illuminating, Stats SA data	37	MJ/ℓ	0,0370	GJ/ℓ	0,79	47
Petrol	34,2	MJ/ℓ	0,0342	GJ/ℓ	0,72	47,3

Source: Department of Energy, Draft 2012 Integrated Energy Planning Report, annexure B, "Model Input and Assumptions (Optimization Model)" (published September 2013).

Greenhouse gas emission factors (Table 4) draw from those of the IPCC for South Africa as well as Eskom data for local electricity emission factors. Local-level reporting protocols dictate consumption as the basis for emissions accounting. Therefore, even if the emissions take place outside the provincial boundary, if they relate to consumption of energy within the provincial boundary, they are accounted for within Limpopo's GHG inventory. Provincial-level inventory, thus, reflect the emission factor relating to the provincial supply 'mix' for energy.

Table 4: GHG emission factors for South Africa

Energy source	Unit	tCO$_2$e per unit				Source
		CO_2	CH_4	N_2O	Total	
Diesel	ℓ	0,0026868	0,0000091	0,0000065	0,0027023	www.emissionfactors.com (Intergovernmental Panel on Climate Change Environmental Protection Agency (EPA) 2015)
Petrol	ℓ	0,0022637	0,0000082	0,0000058	0,002277	
Aviation Gas	ℓ	0,0021915	0,0000078	0,0000056	0,0022049	
Jet Fuel	ℓ	0,0025011	0,0000087	0,0000063	0,0025161	
Paraffin	ℓ	0,0025625	0,0000089	0,0000064	0,0025778	
Heavy furnace oil	ℓ	0,0029532	0,0000095	0,0000068	0,0029696	

Electricity	kWh	–	–	–	0,0010300	Eskom Annual Report, 2011 (incl. transmission and distribution losses)
	kWh	–	–	–	0,0009900	Eskom Annual Report, 2011 (excl. transmission and distribution losses)
Natural gas	ℓ	0,0000020	-	-	0,0000020	www.emissionfactors.com (IPCC 2006, Defra/DECC 2014)
LPG	ℓ	0,0016184	0,0000032	0,0000008	0,0016224	www.emissionfactors.com (IPCC 2006, EPA 2015)
Coal	kg	0,0027920	0,0000065	0,000,0115	0,0028100	www.emissionfactors.com (IPCC 2006)
Marine fuels	ℓ	0,0026868	0,0000091	0,0000065	0,0027023	Set as same for diesel

Source: Compiled by SEA, 2012.

5. Greenhouse Gas Emissions Accounting

5.1. Energy Sector

The estimation of GHG emissions from the energy supply sector for Limpopo is based on Tier 1 with country-specific emission factors and activity data obtained from DOE. The baseline data year for the 2015 GHG Emission Inventory for Limpopo was set for 2013. The major fuels supplying the provincial energy market are electricity, coal and fossil-based liquid fuels, predominantly petrol and diesel. Electricity is almost entirely supplied by state-owned enterprise Eskom, whose fuel supply is primarily coal-derived. Liquid fuels are imported from other provinces where there are refineries. SAPIA reports liquid-fuel sales data to the Department of Energy on a monthly basis. Coal is deregulated, however, and distribution data must be obtained directly from suppliers or consumers.

5.1.1. Electricity Generation

Limpopo's electricity sector is dominated by coal based electricity generation, operated by Eskom. In 2013, one electricity generating plant (Eskom Matimba in Lephalale) operated from within the boundaries of Limpopo Province. Eskom Matimba power station generates a total of gross electricity of 24000 GWh for the base year (2013). A significant amount of fuel is consumed within the province to generate electricity for the national grid. There are two power stations in Limpopo, Eskom Matimba Power Station and Eskom Medupi Power Station which generate their of its electricity from combustion of coal. GHG emissions from coal combustion at these two facilities were not accounted for in Section 3.1. While this plant generates emissions in the province, the electricity it generates is fed into the national grid and not necessarily consumed in the province. Significant amounts (51%) of electricity is exported outside of the province.

Matimba Power Station consists of six coal-fired generating units capable of producing 665 megawatts (MW) of electricity each (total installed capacity of 3990 MW). Units 1 and 2 have a capacity of 88 MW each, and Units 3-5 have a capacity of 102 MW each. The total nominal capacity of the power station is 3690 MW and the annual send out power for 2013 is 24 000 000 000 KWh. The station was commissioned in 1988. All units are base load units that typically run 24 hours a day. The plant operate conventional units that combust coal to generate electricity. Table 5 provides a summary of electricity generation from Matimba Power station for the year 2013.

Table 5: Amount of electricity generated and sent out from power station for the year 2013

Name of station	Matimba
Number and Installed capacity of generator sets (MW)	6 x 665
Total Installed capacity (MW)	3 990
Total nominal capacity (MW)	3 690
Annual Send out Power KWh	24 000 000 000
Annual Consumption KWh	11727000000
Net Generated KWh	12273000000,00

Difference between installed and nominal capacity reflects auxiliary power consumption and reduced capacity caused by the age of the plant (Eskom. 2013)

This report considered electricity-related emissions from both a production and consumption (load) basis. Net energy generation was determined by subtracting the amount of energy consumed within the province from energy produced by the power station within the province (Table 6)

Table 6: Electricity Generation Energy demand (GJ) by energy type and sector, Limpopo, 2013

Electricity Generation	Annual Gross Load	Annual Consumption KWh	Net Generation
Power (KWh)	24 000 000 000	11727000000	12273000000,00
Energy (GJ)	86400000	42 217 200	44182800

In order to compare energy sources, units were converted to joules, the standard energy unit. The energy conversion factors were drawn from the National Department of Energy's (DOE) Draft 2012 Integrated Energy Planning Report (DOE, 2013a). Appropriate emissions conversion factors were sourced from www.emissionfactors.com (using the IPCC's 4th assessment report global Warming Potential) and from Eskom in the case of electricity (Table 3). Total energy consumption is made up of nine fuel categories: electricity, petrol, diesel, paraffin, liquid petroleum gas (LPG), coal, heavy furnace oil (HFO), jet fuel, and aviation gasoline. The energy consumption data analysis disaggregates the province into five sectors: residential, industrial and commercial, transport, agriculture and general according to the premise that energy demand (the where and how energy is consumed) is the basis of provincial level energy management and meeting energy service needs of citizens.

5.1.2. Electricity Consumption

While there are no emissions associated with electricity at the point of use, there are significant emissions at the fossil fuel plant that generates the electricity. Eskom is the only provider of electricity to consumers in the Province. Statistics South Africa (Stats SA) conducts monthly surveys covering electricity undertakings and establishments (branches) in the electricity industry. Stats SA's P4141 (Electricity generated and available for distribution) statistical release contain monthly information regarding the volume of electricity units: generated and distributed in South Africa; flowing into and out from South Africa as measured by the metering systems at the South African borders; and delivered to provinces.

For 2013, the report indicates that a total volume of electricity has been delivered to Limpopo by Eskom is 11 727 Gigawatt-hours including transmission and distribution losses. Although the report does not disaggregate the electricity distribution per sector, this report disaggregates electricity consumption based on the 2006 customers and sales per economic activity by province and entity data reported in the2006 Electricity Supply Statistics for South Africa issued by the National Energy Regulator for South Africa (2016). The percent sales per sector was calculated and applied in the current report (Table 7) Usage amounts within the boundaries of Limpopo, were provided by four categories – residential, commercial, large industrial/commercial, and General. These data represent consumption of electricity.

Table 7: Electricity Consumption per sector

Sector	Electricity (KWh)	% Consumption
Domestic	1301697000	11.1
Agriculture	363537000	3,1
Mining	6637482000	56,6
Manufacturing	2591667000	22,1
Commercial	422172000	3,6
General	410445000	3,5
Total Electricity Consumption	11727000000	100

Electricity usage amounts are divided per customers/sectors serviced by Eskom (Domestic, Agriculture, Mining, Manufacturing, Commercial, Transport and General). In this report, electricity consumption data to be supplied for three categories – residential, transport, industrial and general. For industrial consumption, was obtained by aggregating data for Mining, Manufacturing and Commercial sectors. **Error! Reference source not found.**Table summarizes the provincial electricity consumption distributed per sector.

5.1.3. Liquid fuel consumption

Liquid fuels included in this report are petrol, diesel, liquefied petroleum gas (LPG), paraffin, jet fuel, aviation gasoline, and heavy fuel oil. The South African Petroleum industry association (SAPIA) used to be official body that collected and held data relating to liquid fuel consumption in the country, but since 2009 this function resides with the national DOE. Sales by fuel type data is available publicly on the DOE's website. However data on sales by trade category require a non-disclosure agreement.

This report disaggregates liquid fuel consumption into the residential, commercial, agricultural, transport and other sectors. DOE liquid fuel data provide retail level disaggregation, which show the amount of a particular fuel sold to, say, the commercial sector or the agricultural sector. Unfortunately, certain retail categories (e.g. general dealers and retail-garages) are more difficult to assign to sectors. These were assigned entirely to the transport sector, assumed to have the largest customer base and highest consumption. Liquid fuel consumed in Limpopo is presented in Table 8 below:

Table 8: Provincial Liquid Fuel Sales Volume (Litres) for 2013

Fuel	Sales Volume (l)
Jet Fuel	**3 580 254**
Aviation Gasoline	**924 605**
Diesel	**424 483 028**
Furnace Oil	**24 690 719**
LPG	**3 771 112**
Paraffin	**4 556 892**
Petrol	**403 187 827**

Transportation is considered the main liquid fuel consumer. Sector fuel use was based on the following: i) all petrol consumption was assigned to the transport sector; ii) all diesel consumption was assigned to the transport sector, although an unknown proportion of diesel is used for stationary combustion in the commercial and industrial sectors; iii) all heavy fuel oil consumption was assigned to the industrial sector; iv) paraffin use was assigned entirely to the residential sector; v) LPG consumption was split 25% residential, 75% industrial and commercial use, based on LPG allocations in the Polokwane Energy Strategy. There have been no detailed studies on LPG use in the country and more research is required in the future; vi) all jet fuel and aviation gasoline was assigned to the transport sector.

5.1.4. Solid Fuel (Coal Data)

Unlike liquid fuel, coal sales are not regulated. With the deregulation of coal market, it virtually impossible to obtain province-level consumption data. At a national level, coal consumption data is available in the DOE's energy balances, but no single data portal exists for provincial-level coal use. LEDET's air quality management unit collects data on industrial and commercial coal use, as facilities need to report polluting fuel consumption for atmospheric emission licensing purposes. Figures obtained from air quality unit were estimated to be the total coal consumption for industrial sector. Coal consumption data for the residential sector were derived using a methodology developed by Aurecon Consultancy, allocating an average of 10kg/household/month for cooking and/or space heating. The estimate was based on 2013 General household survey data (Stats SA) was used to determine the number of households using coal for cooking and/or space heating in the province, applying appropriate filters to avoid double counting households reported under both cooking and space heating. This approach only provides rough estimates with sectoral breakdown likely obscure, future explorations should be carried out to obtain more accurate coal consumption data and sectoral breakdown. Table 9 presents coal consumption data for industrial and residential sector.

Table 9: Coal consumption per sector

Sector	Industrial & Commercial	Residential Sector (Kg)	Total Consumption (Kg)
Consumption (Kg)	1 267 502 500	360 000	**1 267 862 500**
% Consumption	99.97	0.03	**100**

5.1.5. Energy balance for Limpopo

Table 10: Energy balance for Limpopo, 2013: native units

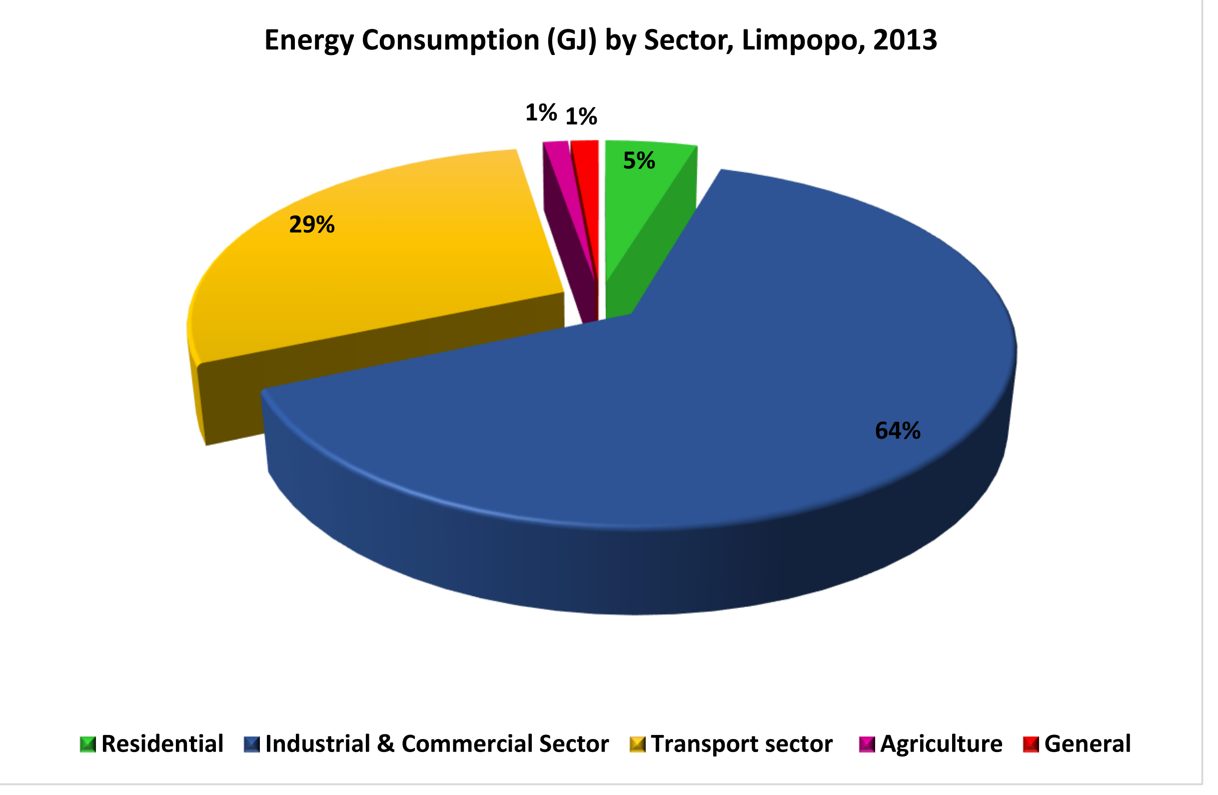
Energy source and unit	Electricity (kWh)	Coal (kg)	Petrol (ℓ)	Diesel (ℓ)	Paraffin (ℓ)	LPG (ℓ)	Jet Fuel	Aviation Gasoline	Furnace Oil
Gross Generation	24 000 000 000								
Net Generation	12273000000								
Total supply	11 727 000 000	1 267 862 500	403 187 827	424 483 028	4 556 892	3 771 112	3 580 254	924 605	24 690 719
Total final consumption	11 727 000 000	1 267 862 500	403 187 827	424 483 028	4 556 892	3 771 112	3 580 254	924 605	24 690 719
Consumption by Sector									
Residential	1301697000	360 000	–	–	4 556 892	942 778	-	-	-
Industrial & commercial sector	9651321000	1 267 502 500	-	-	-	2 828 334	-	-	24 690 719
Transport sector	-	-	403 187 827	424 483 028	-	-	3 580 254	924 605	-
Agriculture	363537000	-	–	–	-	-	-	-	-
General	410445000	-	-	-	-	-	-	-	-

Table 11: Energy consumtion (GJ) by energy type and sector, Limpopo, 2013

Energy Source	Residential	Industrial & Commercial	Transport	Agriculture	General	Total	%Total
Electricity	4686109	34744756		1308733	1477602	42 217 200	40,4%
Coal (bituminous)	8748	30800311	-	-		30 809 059	29,5%
Petrol	-		13 789 024	-		13 789 024	13,2%
Diesel	-		16 172 803	-		16 172 803	15,5%
Paraffin	168 605	-	-	-		168 605	0,2%
LPG	25172	75516	-	-		100 688	0,1%
Jet fuel			122 803			122 803	0,1%
Aviation gas			31 344			31 344	0,0%
Heavy fuel oil		1 027 134				1 027 134	1,0%
Total	4255376	66647717	30749232	1308733	1477602	**104 438 660**	-
%Total	4,1%	63,8%	29,4%	1,3%	1,4%	-	-

Table 12: Energy-related GHG emissions by energy source and sector (tCO_2e), Limpopo, 2013

Energy Source	Residential	Industrial & Commercial	Transport	Agriculture	General	Total	%Total
Electricity	1340748	9940861		374443	422758	12078810	67,82%
Coal (bituminous)	1012	3561682				3562694	20,01%
Petrol			918059			918059	5,16%
Diesel			1147080			1147080	6,44%
Paraffin				11747		11747	0,07%
LPG	1530	4589				6118	0,03%
Jet fuel			9008			9008	0,05%
Aviation gas			2039			2039	0,01%
Heavy fuel oil		73322				73322	0,41%
Total	1343289	13580453	2076186	386190	422758	17808876	
%Total	7,54%	76,26%	11,66%	2,17%	2,37%		


Energy Consumption (GJ) by Sector, Limpopo, 2013
1%
1%
5%
29%
64%
Residential
Industrial & Commercial Sector
Transport sector
Agriculture
General

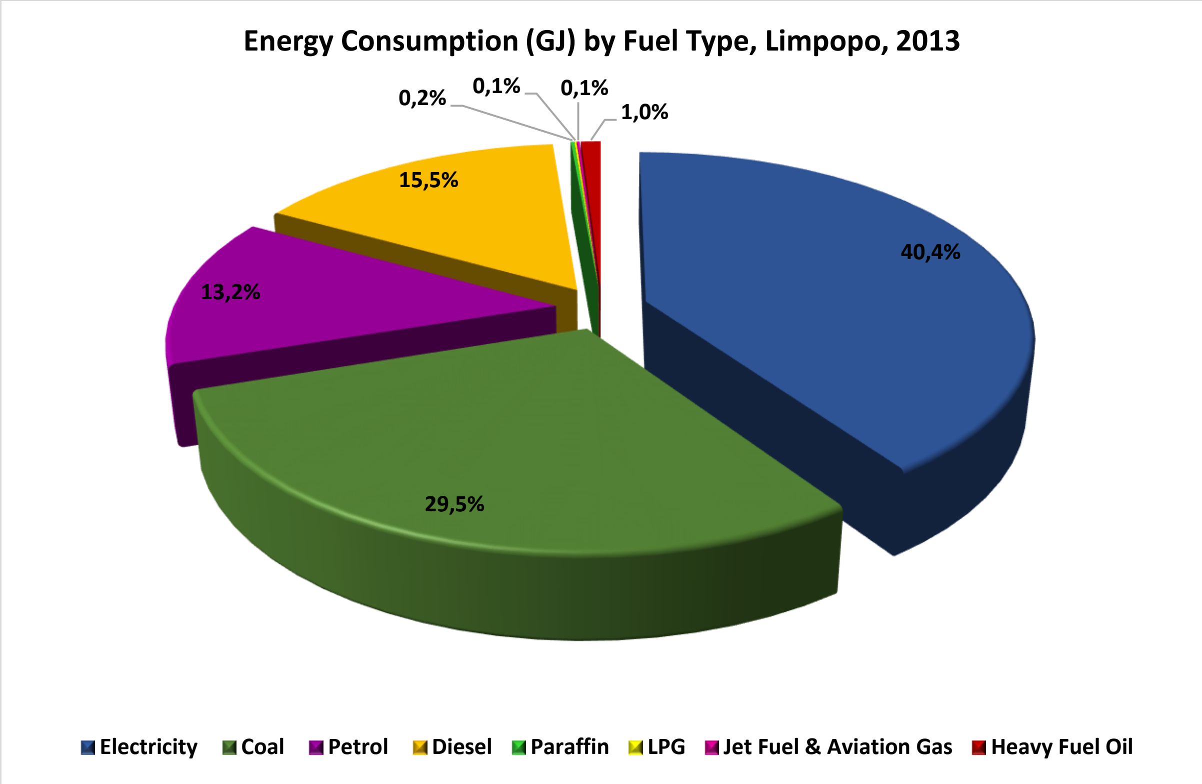


Figure **Energy Consumption (GJ) by Fuel Type, Limpopo, 2013**

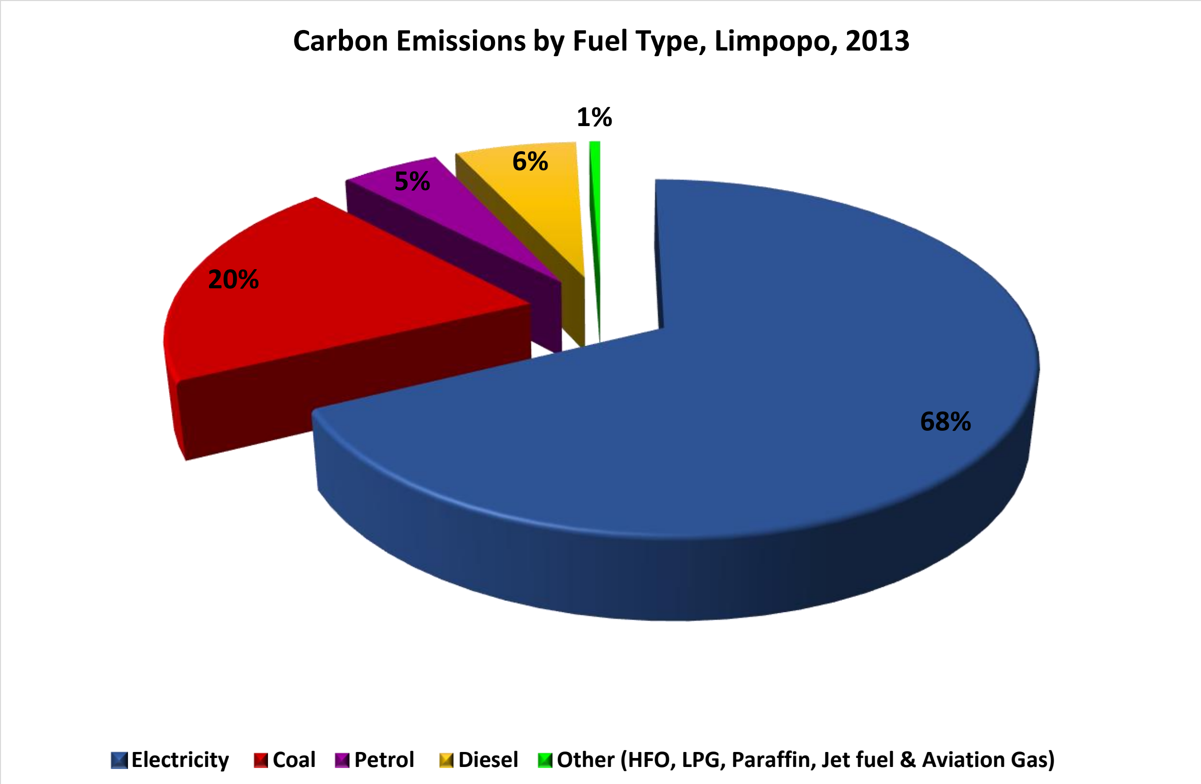


Figure Energy Consumption (GJ) by Sector, Limpopo, 2013

5.1.6. Residential Sector

The broad population data for 2011 was sourced from the last national census (Stats SA 2011). The 2013 population and household numbers used for this report were obtained from Statistics South Africa using the General household survey (2013) and the mid-year populations estimate (2014) reports (Table 13).

Table 13: Limpopo Population Data

Year	2011	2013
Limpopo population	5 404 868	5 517 968
Total number of households	1418102	1 436 000
Average household size	3.7	3.8
Population density (persons per km^2)	42.98	43.88

Understanding household energy use patterns is important for strategy development, both in terms of managing emissions and in terms of welfare. Energy services directly influence human welfare and development through, for example, lights for studying and safety, warmth for health, clean (or not clean) air and the ability to cook and clean. Statistical data indicate a total of 1 436 000 households for 2013. Totals exclude households that did not specify electricity connections and Due to rounding, numbers do not necessarily add up to totals. Values based on three or less un-weighted cases are considered too small to provide accurate estimates (Table 14).

Table 14: Main source of energy used by households for 2013

Energy Use	For cooking	For heating	For lighting
Electricity from mains	769 000	355 000	1 319 000
LPG	17 000	2 000	
Paraffin	50 000	5 000	14 000
Wood	594 000	424 000	2 000
Coal	2 000	3 000	
Candles			90 000
Animal dung		1 000	
None	3 000	645 000	1 436 000
Total	**1 436 000**	**1 436 000**	

The graph below (Figure 2) illustrates household fuel mix in meeting the main household energy needs for cooking, lighting and pace heating.

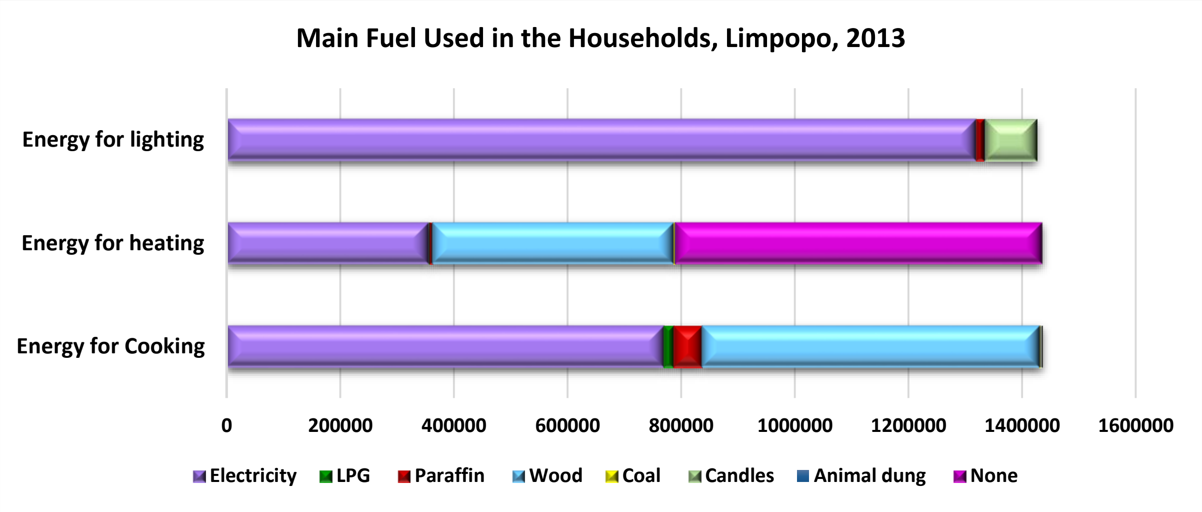


Figure 2: Fuel used for Cooking, Lighting and heating in Limpopo, 2013

Within households, electricity is the major energy source used for lighting (91.9%) and for cooking, although some households still use paraffin and candles for this purpose (Figure 2). The main source of energy for space heating is wood (29.5%) followed by electricity at 24,7% though 45% of households don't use energy for at all for heating their households Despite great reductions, the presence of any candle or paraffin lamp poses an enormous fire risk and health hazard for households. Solar lighting is still in its infancy, but may emerge as a new, safe source of lighting. The major source of energy for cooking is electricity (53.6%). Wood is an alternative source of energy for cooking (41%). Some households across all income bands use gas for cooking, but consumption levels are still low compared with electricity. Paraffin is also still used within low-income bands, though it is declining.

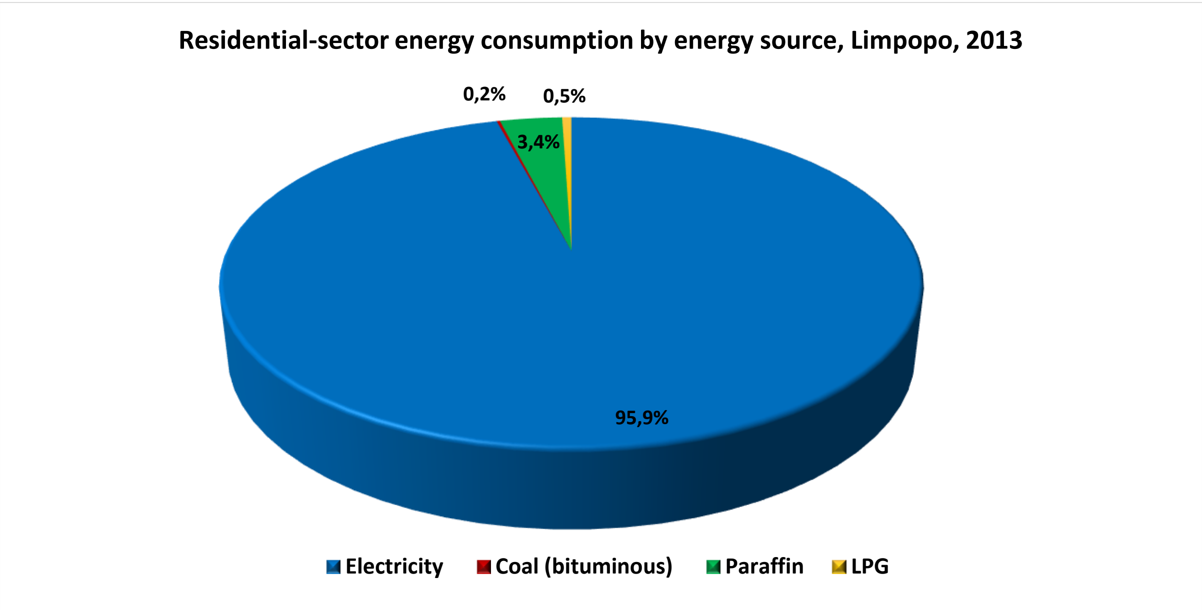


Figure 3: Residential-sector energy consumption by energy source, Limpopo, 2013

Households in Limpopo account for 4.1% of total energy consumption (Table 11) and 11.1% of total electricity consumption (Table 7). Electricity comprises 95.2% of all energy sources used to meet household energy needs, while paraffin and liquid petroleum gas comprise 4% and 0.6% of residential-sector energy consumption respectively (Figure 3).

5.1.7. Industrial (aggregating mining, manufacturing and commercial) Sector

At 63.8% of total energy consumption (Table 11) and 82.4% of total electricity consumption (Table 7), industrial (aggregating mining, manufacturing and commercial) sector dominates the energy picture of Limpopo Province. Electricity is the dominant fuel in the industrial sector combined (51%) (Figure 4). Coal contributes 46% and heavy furnace oil 1.5%. Transport-related energy consumption for these sector is examined as part of the transport sector to avoid double counting.

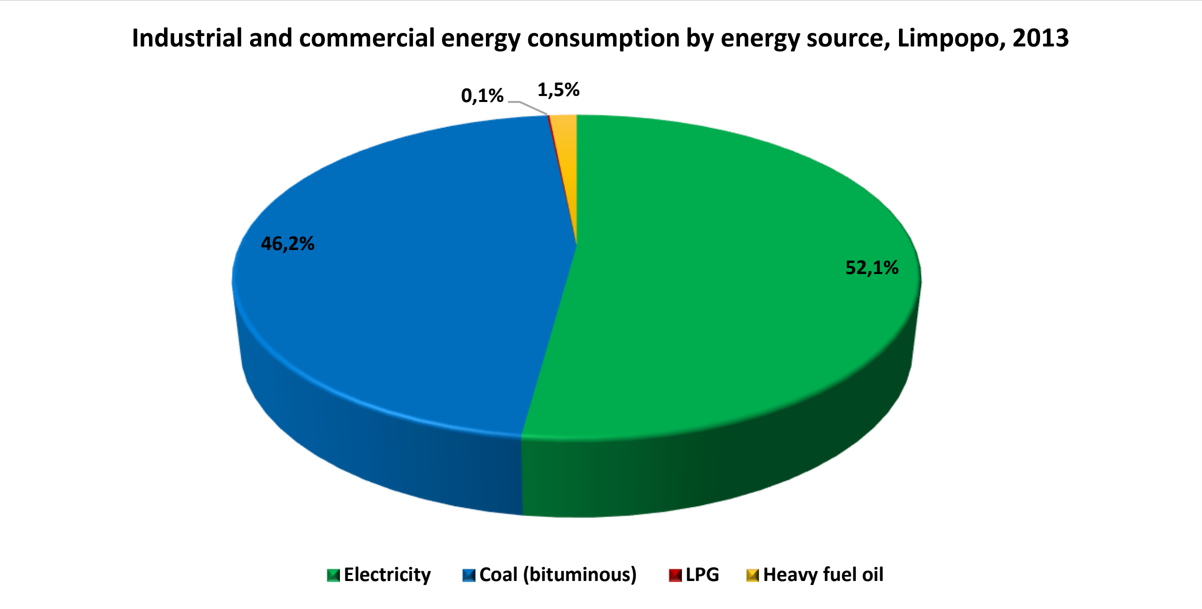


Figure 4: Industrial and commercial energy consumption by energy source, Limpopo, 2013

5.1.8. Transport-Sector Energy

The transport sector accounts for 29% of all energy consumption in Limpopo province. Diesel is the dominant fuel in the transport sector (54%) (Figure 5Figure 4). Petrol consumption contributes 46%. Jet fuel and aviation gas contributes 0.5% combined. In terms of global emissions, local transport accounts for only 29% of GHG emissions, although it does contribute substantially to local air pollution.

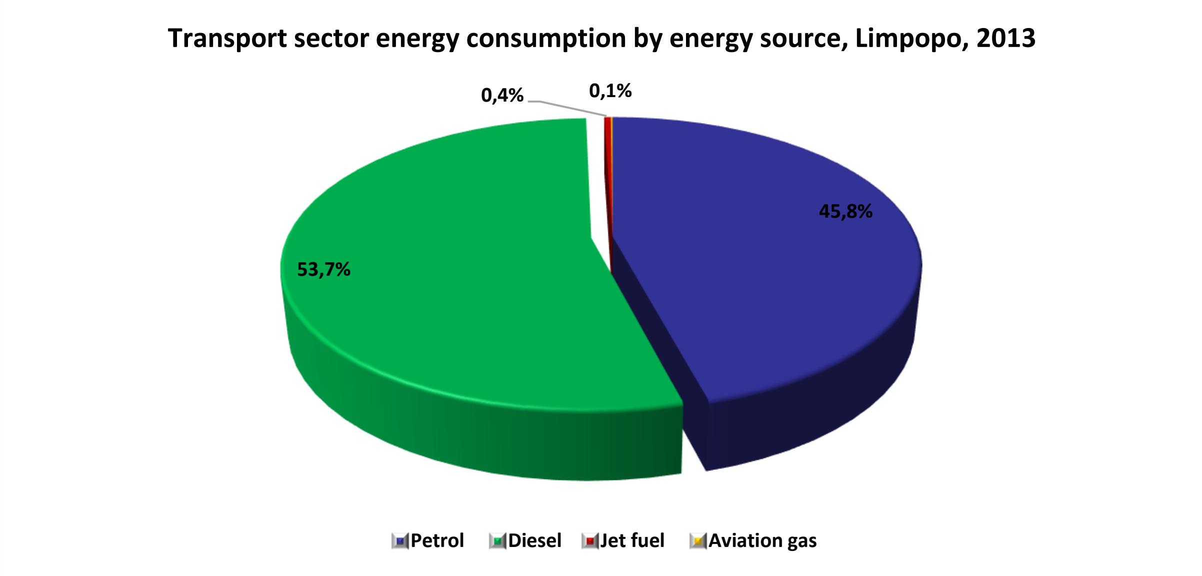


Figure 5: Transport sector energy consumption by energy source, Limpopo, 2013

5.2. Waste Sector

Waste disposal and treatment produces GHG emissions through aerobic or anaerobic decomposition, or incineration. Methane vented to the atmosphere is considered an emission as this action would be adding to atmospheric CH_4. The emissions are multiplied by 21 to calculate the carbon dioxide equivalent (CO_2-e) emissions. Where methane from waste biomass is recovered and flared or combusted for energy, the CO_2 emitted is not counted as an emission but regarded as part of the natural carbon cycle. The total amount of CH_4 recovered is therefore regarded as saved (not emitted) so long as it does not enter the atmosphere as CH_4. Where waste material is diverted from landfill to recycling or to energy use, the reporting entity will have less emissions attributed to its activities because less waste is going to landfill.

5.2.1. Solid Waste

Solid waste is divided into general waste from largely the domestic waste stream, construction waste like builders rubble, commercial waste that would include some industrial waste, hazardous waste which would also include industrial waste and health-care risk waste. Landfilling can result in a positive or negative contribution to GHG emissions, depending on the type of waste and on the management of the waste in the landfill. When carbonaceous material such as paper is buried in a landfill, part of its carbon is sequestrated. This means it can longer enter the atmosphere as greenhouse gas. The remainder of the carbon decomposes to methane and carbon dioxide. Estimates of Scope 1 emissions associated with the disposal of waste can be calculated according to the general equation using activity data and emission factor:

$$tCO_2e \ = Q_j \times EF_j$$

Where

Q_j is the quantity of waste by type j

EF_j is the emission factor of waste type j

Waste emission factors for total municipal waste disposed to landfill were used since there is no available data on the composition of general waste disposed at landfill sites in Limpopo. The factors presented in Table 15 give the weighted average emission factors for the municipal, commercial and industrial, and construction and demolition waste sectors.

Table 15: Waste mission factors for total waste disposed to landfill by broad waste stream

Waste Types	**Municipal Solid Waste**	**Commercial and Industrial Waste**	**Construction and Demolition Waste**
Emission Factor (t CO_2-e	1.2	1.1	0.2

The Limpopo Integrated Waste Management Plan 2012 estimates the amount of solid waste that goes to landfill to be at 2,443,858 tons per annum and therefore 442.89kg/capita/year[17], so the amount of greenhouse gas emissions (tCO_2e) from solid waste landfilling is calculated as follows:

$$tCO_2e \ = Q_j \times EF_j$$
$$= 2\ 443\ 858\ \times 1.2$$
$$= 2\ 932\ 630$$

The amount of GHG emissions generated from landfilling of solid waste is 2 932 630 tCO_2e.

5.2.2. Waste Water

Wastewater services delivery is performed by eleven Water Services Authority in Limpopo through an infrastructure comprising of 67 wastewater collector and treatment system. A total of 123 Ml/day is received at the 67 treatment facilities, which have a collective hydraulic design capacity of 150 Ml/day.

Table 16: Wastewater treatment plants and their capacities in Limpopo

	Micro Size <0.5 Ml/day	Small Size 0.5-2 Ml/day	Medium Size 2-10 Ml/day	Micro Size 10-25 Ml/day	Large Size >25 Ml/day	Undeter-mined	Total Ml/day
No. of WWTPs	5	18	23	1	1	19	67
Total Design Capacity (Ml/day)	1.8	14.8	97.1	11.7	25	19	150.4
Total Daily Inflows (Ml/day)	0.6	3.5	93.0	8	18	48	123.2

[17] LEDET (2012) Limpopo Integrated Waste Management Plan, 2012.

Calculation of GHG emissions from municipal wastewater treatment plants is based on the formula given below:

$$tCO_2e = \left(\left((P \times DC_w) \times (1 - F_{sl}) - COD_{eff}\right) \times MCF_{ww} \times EF_w\right) + (P \times DC_w \times F_{sl} \times MCF_{sl} \times EF_{sl}) - R$$

The parameters used in the above equation are explained in Table 17Table 16 together with a listing of default values.

Table 17: Waste Variable and Default Values

Variable	Default values
P	The population served and measured in persons
DC_w	The quantity in kilograms of Chemical Oxygen Demand (COD) per capita per year of wastewater. In the event that no waste analysis data is available, a default value of 0.585 tonnes per person per year can be used.
COD_w	Chemical Oxygen Demand (COD) in tonnes of COD per year which is the product of DC_w and population
COD_{eff}	The quantity of COD in wastewater discharged in effluent from the treatment plant
F_{sl}	Default fraction of COD removed as sludge. Default value is 0.29
EF_w	Default methane emission factor for wastewater with value of 5.3 tonnes CO_2-e/tonne COD (wastewater)
EF_{sl}	Default methane emission factor for sludge with value of 5.3 tonnes CO_2e/tonne COD (sludge)
MCF_{ww} and MCF_{sl}	Fraction of COD anaerobically treated in wastewater (ww) and sludge (sl). This value varies according to wastewater treatment type. IPCC defaults are: Managed aerobic treatment = 0 unmanaged aerobic treatment = 0.3 Anaerobic digester/reactor = 0.8 Shallow anaerobic lagoon (<2 metres) = 0.2 Deep anaerobic lagoon (<2 metres) = 0.2
R	Recovered methane from wastewater in an inventory year, measured/expressed in tonnes

Aerobic wastewater treatment systems produce primarily CO_2, whereas anaerobic systems produce a mixture of CH_4 and CO_2. The equation above estimates GHG emissions. Assuming that Limpopo facilities operate activated sludge system and an aerobic digester system. Calculation of emissions generated from domestic wastewater is shown below.

COD Calculation:

$$COD_w(tonnes) = Population \times DC_w$$

$$= 5\ 517\ 968 \times 0.0585 = 322801{,}13\ tonnes\ COD$$

Emissions from wastewater treatment calculation:

$$GHG\ emissions\ (tCO_{2e}) = \left(COD \times (1 - F_{sl}) - COD_{eff}\right) \times MCF_{ww} \times EF_w$$

$$= (322801.13 \times (1 - 0.29) - 100) \times 0.8 \times 5.3$$

$$= 971\ 336.5\ tCO_{2e}$$

Emissions from sludge calculation:

$$GHG\ emissions\ (tCO_{2e}) = COD_w \times F_{sl} \times MCF_{sl} \times EF_{sl}$$

$$= 322\ 801.13 \times 0.29 \times 0.8 \times 5.3$$

$$= 396\ 916.3\ tCO_{2e}$$

5.2.3. Total GHG emissions from Waste Sector

Total tons of carbon equivalence from Waste Sector:

$$tCO_2e\ = 2\ 932\ 630 + 971\ 336.5\ + 396\ 916.3$$

$$= \mathbf{4\ 300\ 883}$$

Total GHG emissions from Waste Sector is **4 300 883 tonnes CO_2e**

5.3. Industrial Process and Product Use (IPPU) Sector

The industrial processes and product use (IPPU) sector covers the greenhouse gas emissions resulting from various industrial activities that produce emissions other than from combustion of fuels for energy. Examples include the release of CO_2 as a by-product of cement production, blast furnace in the iron and steel industry, the use of fossil fuel as a feedstock in ammonia production and other chemical products manufactured from fossil fuels used as chemical feedstock. Greenhouse gas emissions from industrial processes other than from combustion of fuels for energy are estimated by using the methods described in this section. IPCC default emission factors can be used for the estimation of GHG emissions from ferroalloy production; however country specific emission factors for the estimation of GHG emissions from ferrochrome production are available from the DEA. These emission factors are national average emissions factors and can be used in the absence of plant- or company-specific data.

5.3.1. Mineral Industry

Three industrial processes are highlighted under the mineral industry, i.e., cement production, lime production, and glass production. For these processes, CO_2 is released from the calcination of carbonate compounds, during which a metallic oxide is formed through heating. A typical calcination reaction for the mineral calcite (or calcium carbonate) is shown below.

$CaCO_3$+ heat → CaO + CO_2

Estimating process-related CO_2 emissions resulting from the use of carbonate raw materials in the production and use of a variety of mineral industry products are discussed in this section of the report. In Limpopo there are no glass production facilities. It follows then that this category covers emissions related to cement production and lime production as described below.

5.3.1.1. Cement Production

Cement production is the most important source of CO_2 emissions among industrial processes. CO_2 is released as a by-product during the calcination process. The calcination process is a reaction through which calcium carbonate ($CaCO_3$) is heated in order to produce lime (CaO). The lime is then combined with some materials containing silica to form dicalcium or tricalciumsilicates. These two elements are among the four major compounds of the clinker. The clinker is an intermediate product, which is used to produce Portland and masonry cement. The production of masonry cement involves additional CO2 emissions.

There are only two cement manufacturing companies operating within Limpopo boundaries, viz. Pretoria Portland Cement Company Ltd. (PPC) and Mamba Continental Cement which was commissioned in 2015. In cement manufacture, CO_2 is produced during the production of clinker, a nodular intermediate product that is then finely ground, along with a small proportion of calcium sulfate [gypsum ($CaSO_4 \bullet 2H_2O$) or anhydrite ($CaSO_4$)], into hydraulic (typically portland) cement (DEA, 2010). In the Tier 1 method, emissions are based on clinker production estimates inferred from cement production data, correcting for imports and exports of clinker.

The estimation of emissions directly from cement production (i.e. applying an emission factor directly to cement production without first estimating clinker production) is not considered to be a good practice method because it does not account for clinker imports and exports (DEA, 2010). In Tier 2, emissions are estimated directly from clinker production data (rather than clinker production inferred from cement production) and a national or default emission factor.

In this report, emissions are estimated from clinker production using an emissions factor. This factor is equal to the amount of CO2 released in tons per tons of clinker produced. The recommended factor is 0.507 tons of CO2 per ton of clinker produced. The annual CO_2 emissions from clinker production is given by:

$$CO_2 Emssions = M_{cl} \times EF_{cl}$$

Where:
CO_2 Emissions is emissions of CO_2 from cement production in tonnes
M_{cl} is weight (mass) of clinker produced in metric tonnes

EF_{clc} is the emission factor for clinker in the particular cement, tonnes CO_2/tonne clinker. The default clinker emission factor (EF_{clc}) is corrected for CKD.

$$CO_2 Emssions = M_{cl} \times EF_{cl}$$

$$= 0.52 \ \times 1\ 252\ 205$$

$$= 651\ 147$$

Total tons of carbon equivalence from Cement Production:

$$tCO_2e \ = 651\ 147$$

5.3.1.2. Lime production

Lime is among the most important chemicals produced in United States in terms of quantity. It is used in construction, pulp and paper manufacturing, and water and wastewater treatment. Lime manufacturing, through limestone heating, generates CO_2 emissions. In Limpopo, lime production occurs in various parts of the province. The only activity data required for the estimation of CO_2 emissions for this sector is annual production amounts. Lime producers include PPC and PBD-Lime.

$$CO_2 Emssions = \sum (EF_{lime,i} \times M_{lime,i})$$

Where:

CO_2 Emissions is emissions of CO_2 from lime production in tonnes

M_{lime} is weight (mass) of lime produced of type *i* in metric tonnes

EF_{lime} is emission factor for lime produced of lime type *i*, tonnes CO_2/tonne of lime produced. The default lime production emission factor (EF_{lime}) is corrected for cement kiln dust (CKD).

Carbon dioxide emissions from the production of lime is determined as follows:

$$CO_2 Emssions = \sum (EF_{lime,i} \times M_{lime,i})$$

$$= 0.75 \times 2\ 750\ 000$$

$$= 2\ 062\ 500$$

Total tons of carbon equivalence from lime Production:

$$tCO_2e \ = 2\ 062\ 500 +$$

5.3.1.3. GHG emissions from Mineral Industry

Table 18: GHG emissions for Metal Industry

Industrial Process	Activity Data	CO_2 Emission Factor (ton emission/ton Product)	CO_2 Emissions (ton)	tCO_2e Emissions (metric tonne)
Cement Production	1 252 205	0.507	634 868	651 147
Lime Production	2 750 000	0.785	2 158 750	2 062 500
Total	**-**	**-**	**2 793 618**	**2 713 647**

Total tons of carbon equivalence from Mineral Industry:

$$tCO_2e \;= 2\,062\,500 + 651\,147$$

$$= \mathbf{2\,713\,647}$$

5.3.2. Metal Industry

Iron and steel production results in emissions of CO_2, CH_4, and N_2O gases. The IPCC (2006) guidelines include the following activities under iron and steel industry: primary facilities that produce both iron and steel; secondary steelmaking facilities; iron production facilities; off-site production of metallurgical coke, and coke production.

5.3.2.1. Metallurgical Coke Production

Metallurgical coke production is considered to be an energy use of fossil fuel, and as a result emissions should be reported in Category 1A of the Energy Sector. The methodologies are presented here in Volume 3, however, because the activity data used to estimate emissions from energy and non-energy in integrated iron and steel production have significant overlap. All fuel consumed in this source category not allocated as inputs to the sinter plants, pelletization plants and blast furnace should be regarded as fuel combustion, which is dealt with and reported in the Energy Sector (see Volume 2: Energy). The IPCC (2006) outlines 3 Tiers for calculating CO_2 emissions and two Tiers for calculating CH_4 emissions from coke production. Metallurgical coke is produced either at the iron and steel facility ("onsite‟) or at separate facilities ("offsite‟). The Tier 1 method calculates emissions from all coke production using default emission factors applied to national coke production. The Tier 1 method assumes that all coke made onsite at iron and steel production facilities is used on-site. The Tier 1 method is to multiply default emission factors by tonnes of coke produced. Emissions should be reported in the Energy Sector.

$$E_{CO_2} = Coke \times EF_{CO_2}$$

Where:

E_{CO_2} is emissions of CO_2 from coke production, tonnes CO_2

EF is emission factor, tonnes CO_2/tonne coke production

Emissions of CO_2 for metallurgical coke production is determined using the equation above and default CO_2 emission factor for metallurgical coke production which is 0.56.

$$E_{CO_2} = Coke \times EF_{CO_2}$$

$$= 186\,500 \times 0.56$$

$$= 104\,440$$

Total tons of carbon equivalence from Coke Production in metric tonnes:

$$tCO_2e \; = 104\,440 \times 0.907 \times 12 \div 44$$

$$= \mathbf{25\,834.7}$$

Note: The Tier 1 method assumes that all of the coke oven by-products are transferred off site and that all of the coke oven gas produced is burned on site for energy recovery. The Tier 2 method estimates CO_2 emissions from onsite coke production separately from off-site production. It produces a more accurate estimate than Tier 1 as it takes into account the actual quantity of inputs into and outputs rather than making assumptions (DEAT, 2010).

5.3.2.2. Ferroalloy production emission

Emissions of CO_2 occur during ferroalloy production as a result of the use of carbon reductants such as coke and the oxidation of a fossil fuel electrode. This section is relevant to the estimation of carbon dioxide emissions from the consumption of a fossil fuel reductant during the production of ferroalloy and silicon. Emissions from production of ferroalloys result due to the high temperature heating of raw ore, carbon materials. Carbon dioxide (CO_2) is released from use of reducing agent, and can be estimated from Tier 1 approach as follows:

$$\boldsymbol{E_{CO_2} = MP_i \times EF_i}$$

Where: E_{CO_2}= CO_2 emissions, tonnes MP_i = production of ferroalloy type i, tonnes EFi = generic emission factor for ferroalloy type i, tonnes CO_2/tonne specific ferroalloy product, Table 4.5 and 4.6 of the IPCC (2006) guidelines.

$$\boldsymbol{E_{CO_2} = MP_i \times EF_i}$$

$$= \mathbf{3\,429\,220 \times 1.64}$$

$$= \mathbf{5\,589\,629}$$

Total tons of carbon equivalence from Ferroalloy Production in metric tonnes:

$$tCO_2e \; = 5\,589\,629 \times 0.907 \times 12 \div 44$$

$$= \mathbf{1\,382\,671}$$

5.3.2.3. Silicon metal Production

CO_2 emissions are estimated as follows:

$$\boldsymbol{E_{CO_2} = MP_i \times EF_i}$$

$$\boldsymbol{= 55\ 000 \times 4.85}$$

$$\boldsymbol{= 26\ 750}$$

Carbon equivalence from Silicon Production in metric tonnes:

$$tCO_2e\ = 26\ 750 \times 0.907 \times 12 \div 44$$

$$\boldsymbol{= 6\ 617}$$

CH_4 emissions are estimated as follows:

$$\boldsymbol{E_{CH_4} = MP_i \times EF_i}$$

Where: $\boldsymbol{E_{CH_4}}$= CH_4 emissions, kg MP_i = production of Si-alloy i, tonnes EF_i = generic emission factor for Si-alloy i, kg CH_4/ tonne specific Si-alloy product, Table 4.7 and 4.8 in the IPCC (2006) guidelines.

$$\boldsymbol{E_{CH_4} = MP_i \times EF_i}$$

$$\boldsymbol{= 55\ 000 \times 1.2}$$

$$\boldsymbol{= 66\ 000}$$

Carbon equivalence from Silicon Production in metric tonnes:

$$tCO_2e\ = 66\ 000 \times 21 \times 0.000907 \times 12 \div 44$$

$$\boldsymbol{= 343}$$

5.3.2.4. GHG emissions from Metal Production

Table 19: GHG emissions for Metal Production

Industrial Process	Activity Data	CH_4 Emission Factor (kg emission/ton product)	CH_4 Emissions (ton)	tCO_2e Emissions (metric tonne)	CO_2 Emission Factor (ton emission/ton Product)	tCO_2e Emissions (metric tonne)	Total
Metallurgical Coke Production	186 500			0.4	0.56	104 440	104 440
Ferrochrome Production	3 429 220				1.6	5 486 752	5 486 752
Silicon Metal Production	55 000	1.2	66	1386	5	275 000	276 386
Total	-	-	**0.34**	**343**	-	**5 720 819**	**5 867 578**

Total tons of carbon equivalence from metal industry:

$$tCO_2e \; = 104\,440 + 5\,486\,752 + 276\,386$$

$$= \mathbf{5\,867\,578}$$

5.4. Agriculture Sector

Emissions of greenhouse gases are produced on agricultural lands as a result of a number of natural and human-induced processes. These include the decay or burning of biomass, feed digestion by ruminant livestock, the addition of nitrogen fertiliser and animal manure, crop residues returned to the soil, nitrogen fixation, nitrogen leaching and runoff, atmospheric deposition, and the anaerobic decomposition of organic matter during flood irrigation. The principal greenhouse gases estimated for agriculture are methane (CH_4) and nitrous oxide (N_2O).

The main agricultural sources of CH_4 are the digestion of feed by livestock, manure management and 'savannah burning' (i.e., the burning of pastoral grassland and woodland). The main agricultural source of N_2O is soils, primarily as a result of the use of nitrogen-based fertilisers on crops and pastures. Manure management and savannah burning are also sources of N_2O. Crop residue burning produces some CH_4 and N_2O.

Tier 1 approach (IPCC, 2006) for livestock emissions from enteric fermentation and manure management was considered for this report. Livestock enteric fermentation and manure management emission estimates require livestock numbers and type of climate region for a Tier 1 approach (IPCC, 2006) and such data for South Africa can be found in DAFF (2013a).

When considering livestock population data, animals destined for slaughterhouses need to be distinguished from those used for dairy and recreational purposes. For CH_4 emissions from enteric fermentation, the activity data required includes the type of digestive system and feed intake. For CH_4 emissions from manure management, information about the manure managed, and manure management practices are needed. Data relating to livestock numbers was acquired from the National Department of Agriculture.

To apportion dairy cattle and beef cattle population numbers from the total cattle population, a ratio was sourced from DAFF's 2013 Trends in the Agriculture Sector. Table Table 1Table 20 provides the estimated livestock population for Limpopo province for the year 2013.

Table 20: Estimated Livestock Population in Limpopo Province, 2013)

Livestock Type	Number of Livestock ('000)
Dairy Cattle*	210
Beef Cattle*	840
Sheep	257
Pigs	350
Goats	1 194
Total	

Source DAFF, 2013. *fraction dairy cattle= 20% and fraction beef cattle=80% of total cattle population adapted from Stats SA 2006 and Stats SA 2011.

5.4.1. Emissions from livestock enteric fermentation

Methane (CH_4) emissions from enteric fermentation for dairy cattle, beef cattle, sheep, pigs and goats was estimated using the activity data and emissions factors presented in Tables Table 1Table 20 and Table 21 respectively. The estimated emissions are provided in Table 22 which shows that to estimate the contribution of cattle to enteric fermentation emissions, population data has to be disaggregated to the level of dairy cattle and beef cattle.

Table 21: CH_4 emission factors for livestock enteric fermentation (Source: IPCC, 2006 and DAFF, 2010).

Livestock	CH4 emission factor (kg CH4 head-1 year-1)
Dairy Cows	92.29*
Beef Cattle	86.1*
Sheep	5
Pigs	1
Goats	5

*Emission factors from DAFF (2010)

Table 22: Estimated livestock emissions CH_4 (Gg) from enteric fermentation

Livestock Type	Number of Livestock ('000)	CH_4 emission factor (kg CH_4 head^{-1} year^{-1})	CH_4 emission (kg CH_4/year)	CH_4 emission (tons CH_4/year)	tCO_2e emitted (tonnes CO_2e/year)
Dairy Cattle	210	92.29	19 380 900	19 380.9	406 998.9
Beef Cattle	840	86.1	72 324 000	72 324	1 518 804
Sheep	257	5	1 285 000	1 285	26 985
Pigs	350	1	350 000	350	7 350
Goats	1 194	5	5 970 000	5 970	125370
Total	**2 851**	**-**	**99 309 900**	**99 309,9**	**2 085 508**

5.4.2. Emissions from manure management

Methane (CH_4) emissions from manure management was calculate from the activity data (Table 20Table 20) and emission factors from IPCC (2006) which are shown in Table 23. The estimated CH4 emissions from manure management are shown in Table 24.

Table 23: CH_4 emission factors for manure management (Source: IPCC, 2006).

Livestock	CH_4 emission factor (kg CH_4 $head^{-1}$ $year^{-1}$)
Dairy Cows	1
Beef Cattle	1
Sheep	0.15
Pigs	1
Goats	0.17

Table 24: Estimated livestock emissions from manure management

Livestock Type	Number of Livestock ('000)	CH_4 emission factor (kg CH_4 $head^{-1}$ $year^{-1}$)	CH_4 emission (kg CH_4/year)	CH_4 emission (tons CH_4/year)	tCO_2e emitted (tonnes CO_2e/year)
Dairy Cattle	210	1	210 000	210	4 410
Beef Cattle	840	1	840 000	840	17 640
Sheep	257	0,15	38 550	38,55	809.55
Pigs	350	1	350 000	350	7 350
Goats	1 194	0,17	202 980	202,98	4 262.58
Total	**2851**		**1 641 530**	**1641,53**	**34 472.13**

5.4.3. Biomass Burning Emissions

2.1. Land Conversion

Land conversion or habitat transformation is a key driver of biodiversity change and as such is one of the more important natural drivers in the Limpopo Province. While habitat transformation does occur naturally on an extended timescale the process is accelerated by anthropomorphic activities such as agricultural conversion, afforestation, urban developments, deforestation and mining. In addition to anthropomorphic activities, habitat transformation can come about through natural effects such as bush encroachment by indigenous species (e.g. Dichrostachys cinerea), which may be related to climate change, or the inhibition of other natural drivers such as frequent veld fires or intermediate disturbances by megaherbivores (Limpopo State of Environmental Report (SoER), 2006). The Limpopo Province is 12 587 283 ha in extent of which 10 717 467 ha (85%) is in a natural or near natural state, and 1 869 816 ha (15%) is not in a natural state (Limpopo CPlan V2, 2013). Table 1 indicates a breakdown of the various land uses and their respective extents.

Table 1: Land Cover of the Limpopo Province based on 2009 SPOT 5 imagery (GeoTerra Image (GTI), 2012)

Natural	10 717 467	85%	Natural	10 661 427	85%
.			Wetlands/Water	16 991	<1%
			Degraded	39 049	<1%
Not Natural	1 869 816	15%	Infrastructure	317 794	3%
			Cultivation	1 454 300	12%
			Man Made Water	19 449	<1%
			Plantation	78 273	1%
Total	12 587 283			12 587 283	

5.5. Baseline Greenhouse Gas Emissions Profile For Limpopo Province

The current GHG profile for the province provides detailed data about the province's sectoral GHG emission levels, with the aim of pinpointing initiatives that will reduce emissions. A detailed assessment of greenhouse gas emissions for each source and sector has been conducted to determine annual emissions and total emissions for the province. Sub-sectors in the land use, land-use change and forestry (LULUCF) sector with emissions and removals for afforestation and deforestation are not included in the provincial total.

For Limpopo province, a preliminary profile of GHG emissions was compiled by reviewing all sources of GHG emissions and calculating these against a baseline year. The assessment includes both direct GHG emissions which are created within the boundaries of the province, like electricity generation and fossil fuel consumption, landfill and wastewater treatment, agriculture and indirect emissions. Based on this, measures to reduce GHG emissions are then recommended. Other sectors such as natural areas and agriculture (including their carbon sequestration or "sink" capacity) were not included in the current inventory due to lack of readily available information.

5.5.1. GHG Emissions by Sector

Greenhouse gas emissions are attributed to four defined sectors: energy; industrial processes; waste and agriculture

Total GHG emissions in 2013 from each of the sectors is shown in (Table 25, Figure 6). Table 25 also shows emissions from the four energy sub-sectors (Industrial, residential, transport and Agriculture and other sources) as a significant percentage of total emissions are attributed to these sub-sectors. A brief description of these sectors, their attributed GHG emissions is provided in the sections below.

Provincial emissions, across all sectors examined, were approximately 45 603 542 metric tonnes of carbon dioxide equivalent ($MTCO_2e$) in 2013 (Table 25, Figure 6). The energy sector is the largest single source of provincial GHG emissions at 67% (30 450 066 tCO_2e) of provincial GHG emissions. The industrial and waste sectors contributes 19% (8 581 225 tCO_2e) and 9% (4 300 883 tCO_2e) respectively to the provincial GHG emissions (Table 25, Figure 6).

5.5.2. GHG Emissions in the Energy Sector

The energy sector involved the consumption of fossil fuel for electricity productions, transportation household heating, cooking and lighting, as well as agricultural and general purposes. Within the Energy Sector, industrial sector (including mining, commercial and manufacturing) generates the largest share of greenhouse gas emissions at 45% (13 580 453 tCO_2e). This is followed by the electricity production sector which accounts for 41% (12 641 190 tCO_2e) and transport sector which accounts for 7% (2 076 186 tCO_2e).Residential, agricultural and other uses account for the remaining 7% of greenhouse gas emissions within the energy sector.

5.5.3. GHG Emissions from Industrial Sector

Within the industrial sector, metal industry generate the largest share of greenhouse gas emissions (68%, 5 867 578 tCO_2e) while the mineral industry generates 32%, 2 713 647 tCO_2e of GHG emissions

5.5.4. GHG Emissions from Waste Sector

Within the waste sector, municipal solid waste management generates the largest share of greenhouse gas emissions (68%, 2 932 630 tCO_2e) while the wastewater management generates 32%, 1 368 253 tCO_2e of GHG emissions

5.5.5. GHG Emissions from Agricultural Sector

Within the agricultural sector, enteric fermentation from livestock generates the largest share of greenhouse gas emissions (92%, 2 085 508 tCO_2e) while biomass burning generates 7%, 151 388 tCO_2e and manure management generates 1% (34 472 tCO_2e) of GHG emissions.

Table 25: Limpopo Greenhouse Gas Emission by Sector, 2013

Sector	Emissions ($MtCO_2e$)	Percent Contribution
A. Energy		
Net Electricity Production	12 641 190	
Fossil Fuel Consumption	17 808 876	
i. Residential	1 343 289	
ii. Industrial	13 580 453	
iii. Transport	2 076 186	
iv. Agriculture and other uses	808948	
Total Emissions from Energy Sector	**30 450 066**	**67%**
B. Industrial Processes		
Mineral Industry	2 713 647	
Metal Industry	5 867 578	
Total Industrial Emissions	**8 581 225**	**19%**
C. Waste		
Municipal Solid Waste	2 932 630	
Wastewater	1 368 253	
Total Emissions from Waste Sector	**4 300 883**	**9%**
D. Agriculture		
Enteric Fermentation	2 085 508	
Manure Management	34 472	
Biomass Burning	151 388	
Total Emissions from Agricultural Sector	**2 271 368**	**5%**
Gross Emissions	**45 603 542**	**100%**

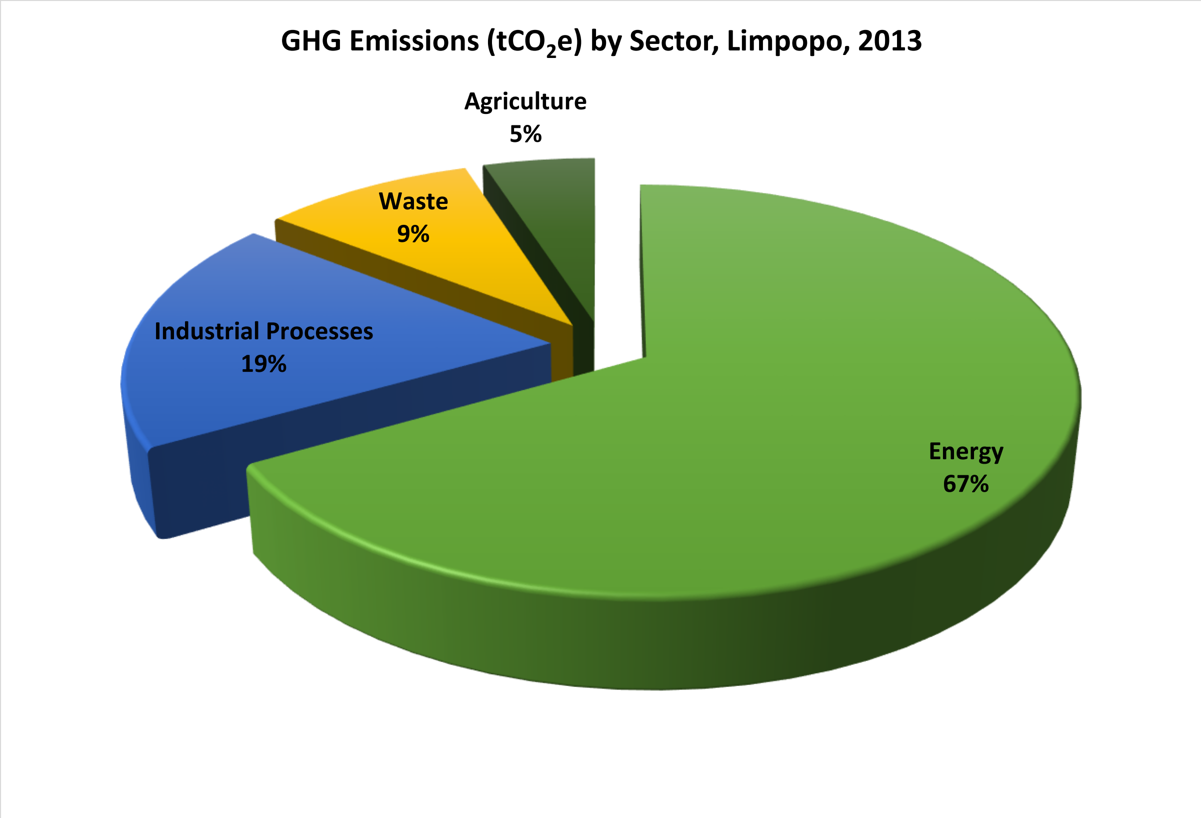


Figure 6: Greenhouse Gas Emissions (tCO2e) by Sector, Limpopo, 2013

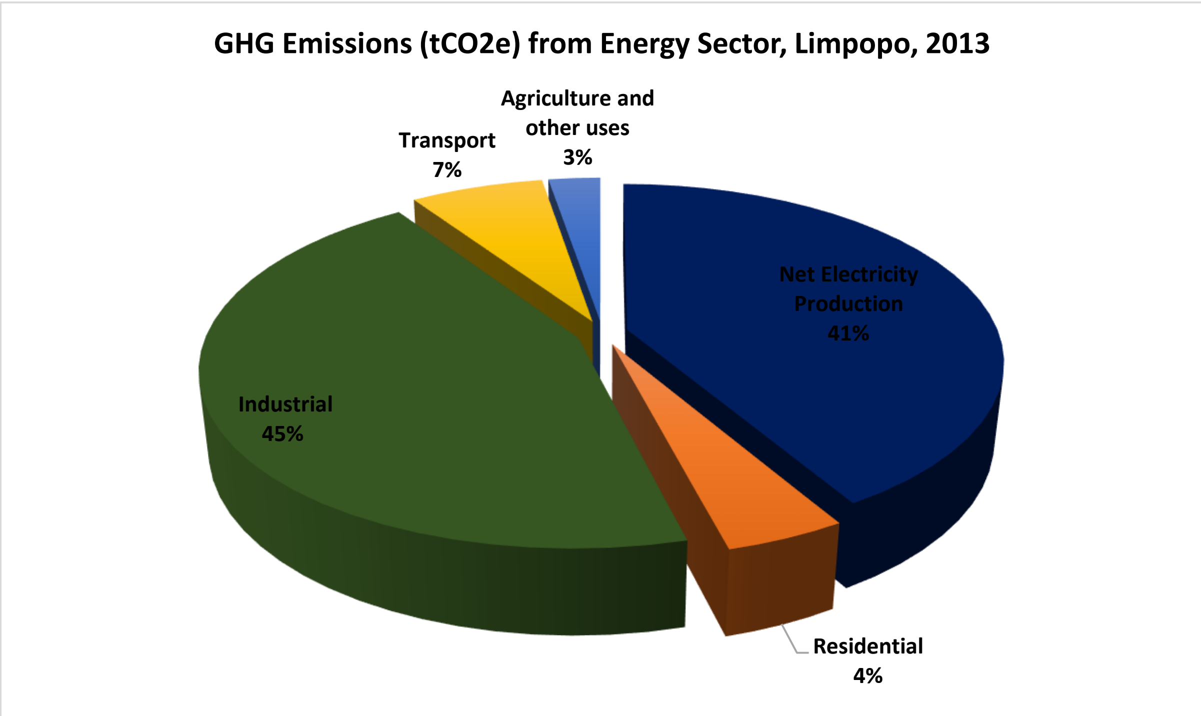


Figure 7: Greenhouse Gas Emissions (tCO_2e) for Energy Sector by Sub-sector, Limpopo, 2013

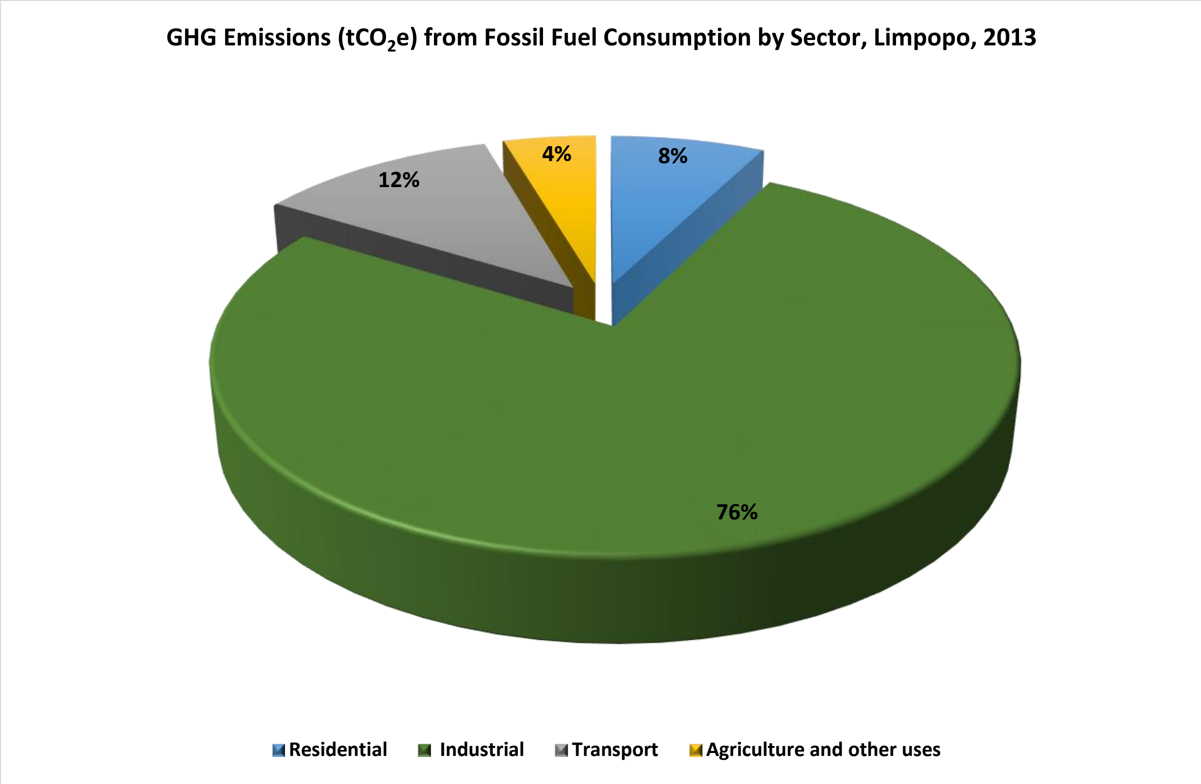


Figure 8: Greenhouse Gas Emissions (tCO_2e) for the Energy Sector (Fossil Fuel Consumption) by Sub-sector, Limpopo, 2013

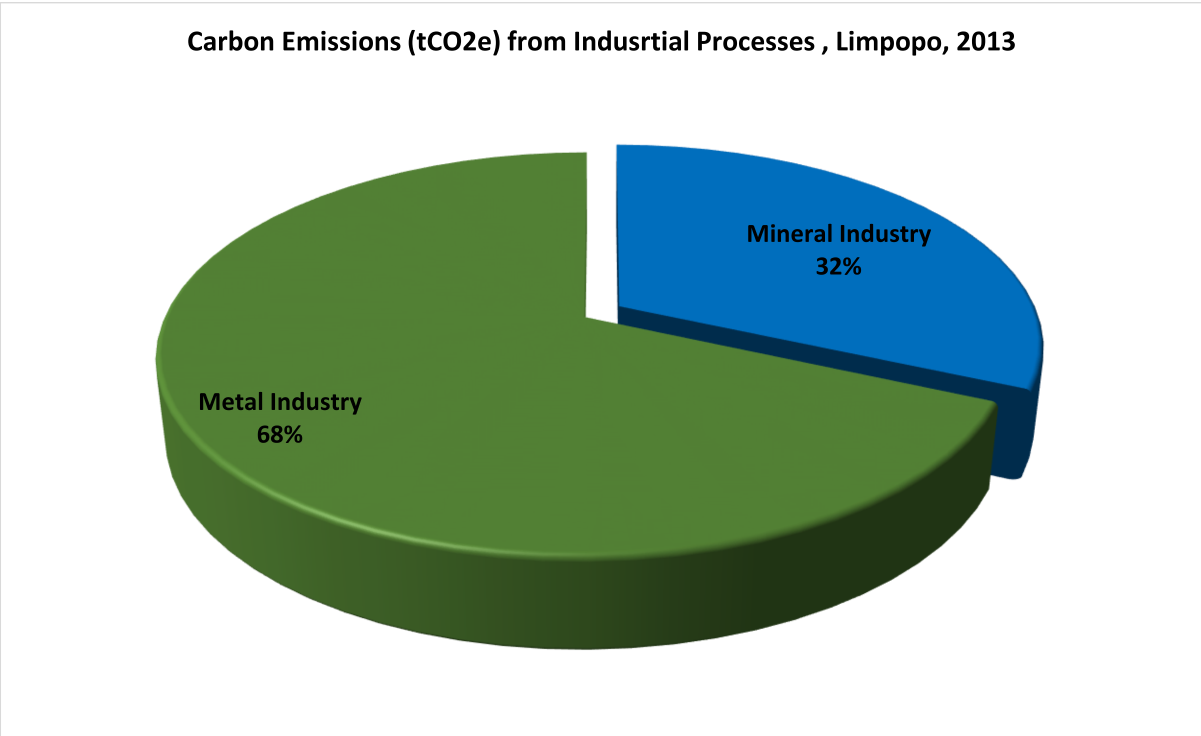


Figure 9: Greenhouse Gas Emissions (tCO2e) by Sector, Limpopo, 2013

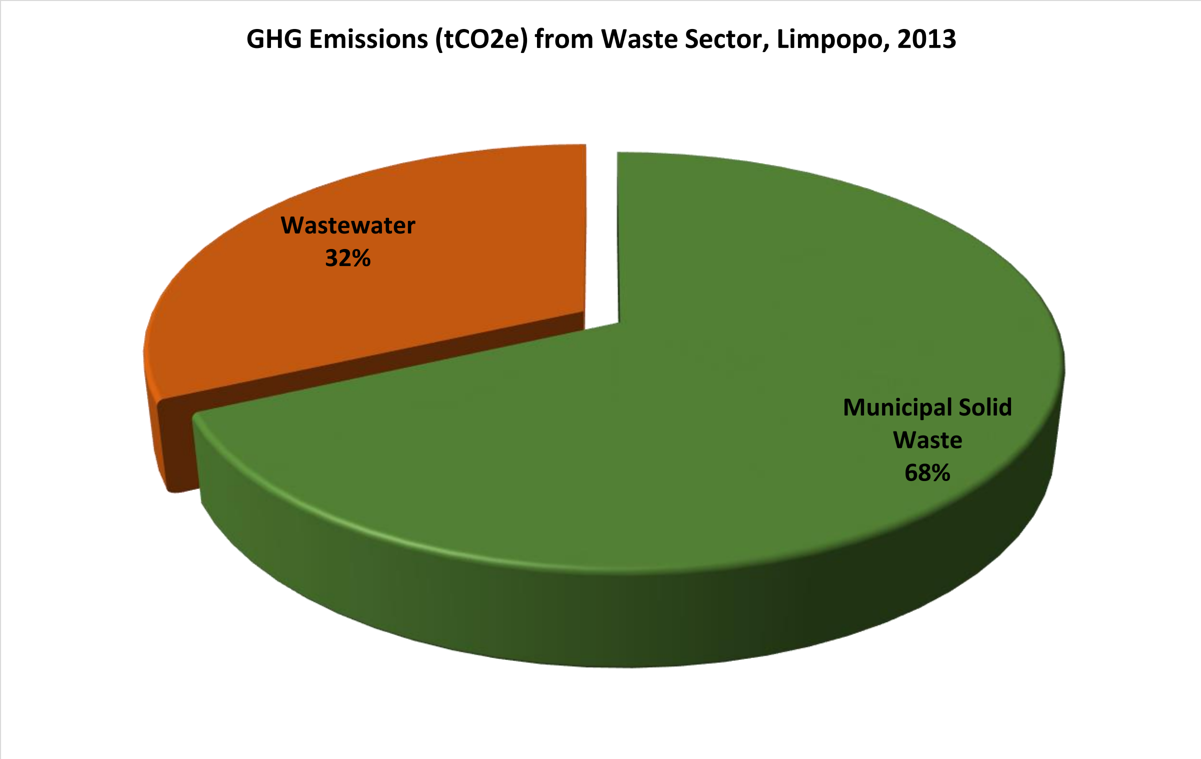


Figure 10: Greenhouse Gas Emissions (tCO2e) by Sector, Limpopo, 2013

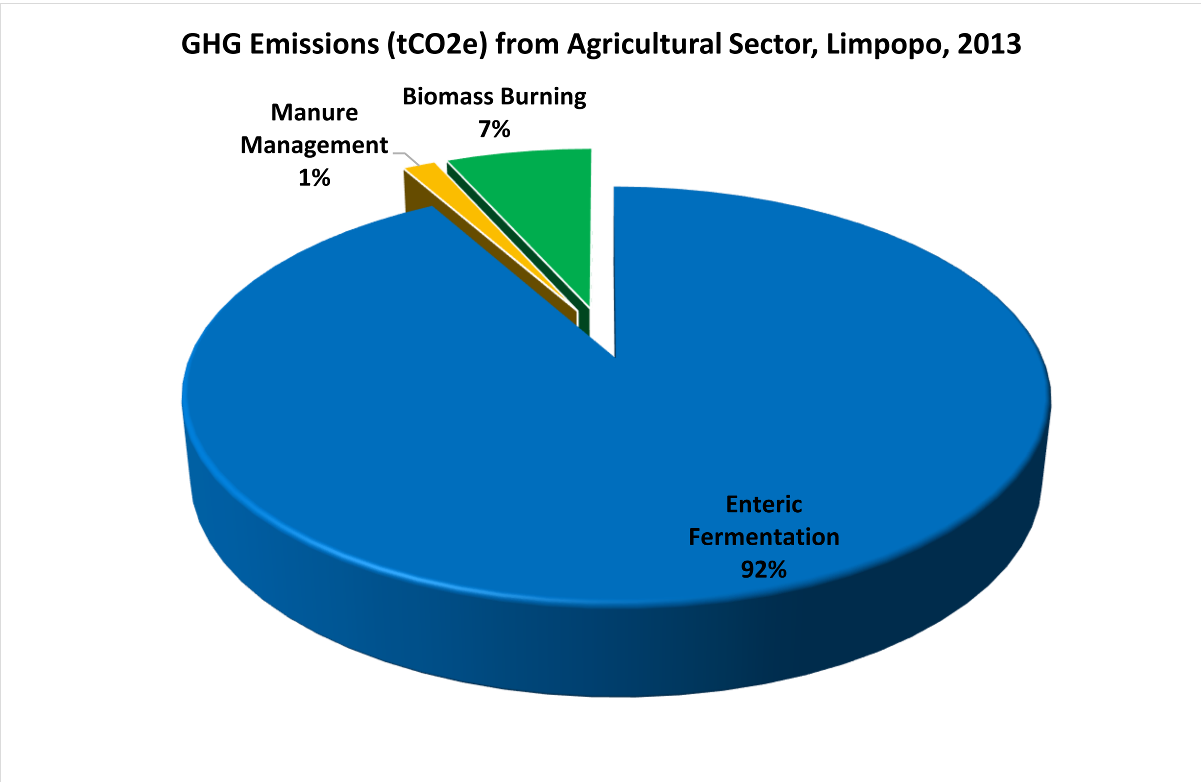


Figure 11: Greenhouse Gas Emissions (tCO2e) by Sector, Limpopo, 2013

6. Climate Change Mitigation Measures

To achieve the provincial GHG emission reduction objectives, a number of mitigation measures have been identified. Clean energy generation and utilization is key and central to addressing climate challenges as most of the greenhouse gasses are generated in the process of fossil fuel combustion. Current production and consumption patterns and behaviours within the province are areas of concern. A variety of interventions to optimize production and consumption patterns necessary to achieve GHG emission reductions are presented below. It is pertinent to note that given the scale of the emissions reduction challenge, it is emphasized that all of the available mitigation options require action from all relevant sectors and through partnerships.

6.1. Renewable Energy and Energy Efficiency

Energy production and use of non-renewable fuels – oil, natural gas, coal, is the largest significant source of greenhouse gas, smog forming pollutants, and acid rain. Emissions can be reduced simply from the promotion of energy conservation and demand management initiatives. Increasing the use of alternative energy (i.e. wind, hydro, solar) in the supply mix will lower the demand for non-renewable sources and reduce greenhouse gases.

Deviation from the fossil based energy to clean energy can be in whole (off grid) or in part (on grid). Solar energy alternatives allow for both. Solar energy systems are dependent on sunlight and therefore highly suitable for Limpopo as the province has eighty to ninety five percent sunlight presence during the day time. It is only the eastern eighth of the province that experience seventy to eighty percent sunlight presence during the day time (which is still acceptable for solar energy systems). Both on grid and off grid solar systems provides a savings in the consumption of fossil fuel based energy system is concern.

I. **Off grid solar energy program:** This option provides for solar components that are absolutely dependent on solar energy supply. An off grid solar system refers to a component that does not need/have grid based energy back up, irrespective of whether it’s done in an area that has electricity supply or not. This could be in the form of components such as solar geysers, lighting systems, water pumps or even the whole household solar energy system. The latter only excludes stoves whereby gas stove is used.

II. **On grid solar energy program:** This option provides for components that use both solar and grid energy supply. On grid solar system refers to components that have a grid based energy back up and therefore confined to areas that have grid electricity supply necessarily. This could be in the form of solar geysers, lighting systems, water pumps or the whole household solar energy system.

III. **Clean wind energy program:** This option usually provides for water pump components whereby wind energy is used to propel the water pump. The system is commonly used for livestock water supply thus circumventing the high cost of drawing electricity to a far-away water borehole. Wind borne electricity systems are less reliable for domestic or industrial use compared to solar energy systems and not recommended for domestic or industrial use.

IV. **Green Building:** Reducing the amount of energy used in buildings is one of the principal potential sources of emission savings that are quick and easy to realize. Limpopo enjoys relatively warm to high temperatures in both winter and summer. However this climatic condition is not considered and built into the design of various private and public buildings. To the latter effect, most of these buildings have to be conditioned to be at acceptable room temperature through the use of fossil based energy thus aggravating the negative impacts of climate change. Design (e.g., roof height and glass space) and material (thatch roof) are the key factors affecting room temperature adaptation to climatic conditions. Green building designs are encourage at both private and public buildings. Measures to reduce energy demand and stimulate energy retrofits as well as renewable energy within private and public building should be implemented to reduce the carbon footprint within the province.

6.2. Waste Reduction and Resource Efficiency

Landfilling is the most common waste disposal method and, in many cases, the one that produces the most greenhouse gas emissions when there is no landfill gas capture system in place. As organic material decomposes in a landfill it releases GHG emissions. Recycling, composting, and other waste reduction and diversion efforts are important strategies for reducing GHG emissions, prolonging the life of landfills, and reducing disposal costs.

I. **Reduce the amount of waste sent to landfills: Major** expanses of land and facilities are required to accommodate waste, and monitoring and mitigation are needed long after disposal. Actions that promote diversion of solid waste from landfills, such as recycling, composting and waste-to-energy initiatives, can reduce GHG emissions, prolong the life of landfills, and reduce disposal costs.

II. **Maintain programs for ensuring that solid waste is managed in a manner that protects health, safety, and the environment.** Reducing waste generation and increasing reuse and recycling will reduce methane emissions as well as associated energy emissions from transportation and treatment.

III. **Expand and strengthen provincial waste recycling programs:** Recycling can have a large impact on reducing greenhouse gases, because it replaces some of the raw materials and energy used in the manufacturing process. Using recycled material not only reduces emissions used to produce these products, but also the energy required for manufacturing. For materials that require intensive processing, such as steel, plastic and aluminium, recycling can reduce emissions by about two tonnes of carbon dioxide equivalent per tonne of product. Paper recycling also increases carbon storage because it leaves more trees growing in the forest. Composting is an option available only for food scraps and yard waste. Because it involves aerobic decomposition, composting does not generate methane emissions, and only releases a small amount of carbon dioxide.

IV. **Develop and Implement programs and policies to encourage waste reduction and diversion by all sectors including residential and commercial.** Transportation of waste to disposal sites produces greenhouse gases from the combustion of the fuel used in the equipment. Finally, the disposal of materials indicates that new products are being produced as replacements. This production often requires greater use of fossil fuels to obtain raw materials and manufacture the items. Cleveland, starting with policies that restrict certain materials, such as plastic bags, or divert others, such as organic waste, are important tools in encouraging waste reduction both at the residential and commercial level. Furthermore, a coordinated approach provides consistent messaging and education to guide businesses and community members. For example, outreach to businesses could include guidelines for sustainable purchasing policies, supply chain engagement, zero waste events, hazardous materials diversion, and incentives for meeting waste reduction targets.

V. **Develop and implement a sustainable integrated waste and energy plan for the province.** The anaerobic decomposition of waste in landfills produces methane, a greenhouse gas 21 times more potent than carbon dioxide. Incineration, a less common disposal method, results in emissions of both carbon dioxide and nitrous oxide. Combusted waste can displace the burning of fossil fuels by producing electricity or heat for nearby buildings or industry. A variety of technologies exist to convert waste into energy or usable materials that reduce GHG emissions. Sustainable, cost effective and long-term solid waste management solution are essential. The solution will include recycling and keeping organic waste out of the landfill and/or landfill methane gas recovery. There is potential for energy generation – whether through anaerobic digestion or the creation of refuse derived fuel (RDF) pellets.

6.3. Transport and Land Use Management

Land use decisions impact nearly all sources of greenhouse gas emissions. Smart growth development bring people closer to more destinations and supports low carbon travel choices (public transit, carpooling, walking and biking). Mixed use, compact developments also result in reduced per capita demand for electricity, heating, and cooling. There are also co-benefits of land use and space management beyond GHG reduction, including preservation of agricultural land, open space, and habitat; improved water quality from reduced development related pollutant sources; positive health effects; and the reduction of smog forming pollutants. Reducing fuel consumption, vehicle emissions and vehicle miles traveled (VMT) are important emission-reduction strategies.

I. **Restore and regenerate the natural environment:** Trees provide many beneficial functions in cities, from helping capture and store carbon dioxide to providing shade and cooling to minimize the “heat island” effect. By valuing and leveraging the natural environment in new ways, Limpopo can create new sources of economic value while also creating a healthy and attractive place to live, work, and play.

II. **Coordinate land use and site design decisions that promote walking, cycling, and taking public transportation.** Local government have the authority to decide how and where land is developed to accommodate population growth. Expanding the opportunities for reduced car travel will make a major contribution to GHG emissions reduction as well as quality of life.

III. **Reduce congestion and vehicle emissions:** Carpooling for commuters and car sharing for individuals making personal trips can reduce fuel use, parking costs, vehicle costs, and traffic congestion. Additional ways to reduce transportation related emissions include encouraging residents and businesses to purchase more fuel efficient vehicles, supporting improvements to national fuel efficiency standards, and reducing the carbon intensity of fuel sources.

IV. **Promoting smart mobility including:** Driving behaviors, such as excessive idling, have a significant impact on fuel consumption and unnecessarily contributes to air pollution. Efforts to improve traffic management and synchronize traffic lights can reduce emissions across the board by reducing congestions and delays.

V. **Encourage and support transport modal shifts:** Increasing the use of transportation options such as public transit, cycling, and carpooling reduces congestion on roadways and transportation related emissions while providing health benefits, such as increased activity levels and improved air quality. Shifting from driving to cycling or walking as the preferred mode of transportation can reduce GHG emissions, save residents' money from reduced fuel costs, and also provide health and fitness benefits.

6.4. Industrial Emission Reduction through Cleaner Production and Resource Efficiency

Strategies focused on the commercial and industrial sector seek to reduce GHG emissions (mainly CO_2) through energy conservation and efficiency, and through the utilization of alternative energy technologies and fuels. While global climate change remains a key environmental driver, the incentives for almost all strategies that focus on conservation, efficiency, and alternative energy options are the economic benefits to the end user.

Industrial production can directly or indirectly cause emissions of greenhouse gases. Extracting raw materials, manufacturing, transporting finished goods, packaging, and disposal of the product all use energy and hence result in emissions of greenhouse gases. Using products more efficiently to ultimately reduce waste also reduces emissions of greenhouse gases. For example, making products and goods from recycled materials reduces the amount of raw materials that have to be extracted, transported and processed.

Often energy consumption is less for manufacturing recycled products compared to making the same product from raw materials. In addition, less waste results in less decomposition of waste avoiding emissions of methane from landfills. The more efficiently we use products and goods from obtaining the raw materials to manufacturing, to use and disposal; the less greenhouse gas emissions are generated because less energy is used or less new products are needed. There is a diverse portfolio of options for mitigating greenhouse gas emissions from the industrial sector, including energy efficiency, fuel switching, combined heat and power, renewable energy sources, and the more efficient use and recycling of materials.

In addition, certain products can be direct sources of greenhouse gases. Operation and maintenance of industrial equipment, particularly electrical equipment, is often a source of emissions of other greenhouse gases. Though the relative quantity of these greenhouse gases may be low, they can be significant because they can have very high global warming potentials.

I. **Energy efficiency in commercial buildings sector:** In the commercial buildings sector, emissions are generated primarily from space heating, lights and fixtures, space cooling, and office equipment. The strategies used to reduce emissions include energy-saving measures, such as reducing overall power consumption and high efficiency replacement equipment. Improving energy efficiency means changing energy consuming equipment or practices to reduce the energy used, without changing the ultimate service that the equipment or practice provides. Higher-than-average efficiency technologies exist for almost every use. Examples include installing efficient new heating systems in buildings, and energy efficiency improvements such as increased building insulation, and optimization systems for lights and heating/cooling, and more efficient windows.

Design improvements, which are most cost-effectively achieved at the time of construction, also present significant opportunities to improve energy efficiency. Designs that take advantage of sun and shade, storage of solar energy (even in passive materials such as floor tile), and more technologically advanced insulation help to improve energy efficiency. In addition, updated building codes (and their enforcement) can play an important role in ensuring greater energy efficiency.

II. **Implement sector-wide options for resource and energy efficiency:** Some mitigation options can be used across many different industries, for example energy efficiency improvements for cross-cutting technologies, such as electric motor systems, can yield benefits across diverse sub-sectors. Other sector-wide mitigation options include the use of fuel switching, combined heat and power, renewable energy sources, more efficient electricity use, more efficient use of materials and materials recycling, and carbon capture and storage.

Alternative energy technologies and fuels involve switching to energy sources that result in lower GHG emissions. For example, natural gas is less carbon intensive than oil and coal, and natural gas systems are often times more efficient in operation than systems those that use oil and coal. The use of renewable energy sources result in zero net CO_2 emissions. Renewable energy options include passive solar heating, active solar water and space heating, and wind and solar electricity generation. Alternative energy technologies and fuels also have ancillary environmental benefits over traditional fossil fuels, including significantly reduced emissions of particulate matter, sulfur compounds (SOx, which lead to acid rain), nitrogen oxides (NOx, which contribute to the formation of ground level ozone and nitrates), carbon monoxide, and non-methane volatile organic compounds (VOCs).

III. **Implement process-specific mitigation options:** Certain mitigation opportunities come from improvements to specific processes and are not applicable across the entire sector. For energy-intensive industries, process improvements can reduce energy demand and, therefore, greenhouse gas emissions and energy costs. Other improvements can reduce emissions of non-CO_2 gases with high global warming potentials.

IV. **Implement measures improve standard operating procedures for specific industries:** A variety of mitigation opportunities can be achieved through improvements to standard operating procedures. These options can include making optimal use of currently available technologies, such as improving insulation and reducing air leaks in furnaces.

6.5. Agricultural Sector Emission Reduction

There is a wide range of actions that can be take in order to enhance the efficiency with which agricultural resources are used, thereby reducing their greenhouse impacts and improving productivity at the same time. Opportunities for mitigating GHGs in agriculture fall into three broad categories based on the underlying mechanism, i.e., reducing emissions, enhancing removals and avoiding (or displacing) emissions. Agricultural ecosystems hold large reserves of carbon and releases significant amounts of CO_2, CH_4 and N_2O to the atmosphere. Reducing emissions involves the reduction of the fluxes of these gases by managing more efficiently the flows of carbon and nitrogen in agricultural ecosystems. Any practice that increases the photosynthetic input of carbon or slows the return of stored carbon via respiration or fire will increase stored carbon, thereby 'sequestering' carbon or building carbon 'sinks'. Many studies worldwide have now shown that significant amounts of soil carbon can be stored in this way, through a range of practices suited to local conditions. Significant amounts of vegetative carbon can also be stored in agroforestry systems or other perennial plantings on agricultural lands. Agricultural lands also remove CH_4 from the atmosphere by oxidation, but this effect is small when compared with other GHG fluxes.

Crops and residues from agricultural lands can be used as a source of fuel, either directly or after conversion to fuels such as ethanol or diesel. These bioenergy feedstocks still release CO_2 upon combustion, but now the carbon is of recent atmospheric origin (via photosynthesis), rather than from fossil carbon. The net benefit of these bioenergy feedstocks to the atmosphere is equal to the fossil-derived emissions displaced less any emissions from their production, transport and processing. Emissions of GHGs, notably CO_2, can also be avoided by agricultural management practices that forestall the cultivation of new lands now under forest, grassland or other non-agricultural vegetation.

Many practices have been advocated to mitigate emissions through the mechanisms cited above. Often a practice will affect more than one gas, by more than one mechanism, sometimes in opposite ways, so that the net benefit depends on the combined effects on all gases. In addition, the temporal pattern of influence may vary among practices or among gases for a given practice; some emissions are reduced indefinitely, other reductions are temporary. Mitigation options for agriculture are listed below:

I. **Cropland management:** Croplands, because they are often intensively managed, offer many opportunities to impose practices that reduce net emissions of GHGs. Mitigation practices in cropland management include agronomy, nutrient management, tillage/residue management, water management, agro-forestry, Land cover (use) change
II. **Grazing land management and pasture improvement:** Grazing lands occupy much larger areas than croplands, but are usually managed less intensively. Some examples of practices to reduce GHG emissions and enhance removals include grazing intensity, increased productivity (including fertilization), nutrient management, fire management, Species introduction
III. **Management of organic soils:** Organic soils contain high densities of carbon, accumulated over many centuries, because decomposition is suppressed by absence of oxygen under flooded conditions. To be used for agriculture, these soils are drained, which aerates the soil, favouring decomposition and therefore high fluxes of CO_2 and N_2O. Methane emissions are usually suppressed after draining, but this effect is far outweighed by pronounced increases in N_2O and CO_2. Emissions on drained organic soils can be reduced to some extent by practices such as avoiding row crops and tubers, avoiding deep ploughing and maintaining a more shallow water table, but the most important mitigation practice, probably, is avoiding the drainage of these soils in the first place, or re-establishing a high water table where GHG emissions are still high.

IV. **Restoration of degraded lands:** A large fraction of agricultural lands have been degraded by erosion, excessive disturbance, organic matter loss, salinization, acidification or other processes that curtail productivity. Often the carbon storage in these soils can be at least partly restored by practices that reclaim productivity including: re-vegetation (e.g. planting grasses); improving fertility by nutrient amendments; applying organic substrates such as manures, bio-solids and composts; reducing tillage and retaining crop residues; and conserving water. Where these practices involve higher nitrogen amendments, the benefits of carbon sequestration may be partly offset by higher N_2O emissions.

V. **Livestock management:** Livestock, predominantly ruminants such as cattle and sheep, are important sources of CH_4, accounting for approximately 18% of global anthropogenic emissions of this gas. The methane is produced primarily by enteric fermentation and voided by eructation). Practices for reducing CH_4 emissions from this source fall into three general categories: improved feeding practices, use of specific agents or dietary additives, and longer term management changes and animal breeding.

VI. **Manure management:** Animal manures can release significant amounts of N_2O and CH_4 during storage, but the magnitude of these emissions varies. Methane emissions from manure stored in lagoons or tanks can be reduced by cooling or covering the sources, or by capturing the CH_4 emitted. The manures can also be digested anaerobically to maximize retrieval of CH_4 as an energy source. Storing and handling the manures in solid rather than liquid form can suppress CH_4 emissions, but may increase N_2O formation. Preliminary evidence suggests that covering manure heaps can reduce N_2O emissions. For most animals worldwide, there is limited opportunity for manure management, treatment or storage – excretion happens in the field and handling for fuel or fertility amendment occurs when it is dry and methane emissions are negligible. To some extent, emissions from manure might be curtailed by altering feeding practices or by composting the manure, but these mechanisms and the system-wide influence have not been widely explored. Manures also release GHGs, notably N_2O, after application to cropland or deposition on grazing lands.

VII. **Bioenergy:** Increasingly, agricultural crops and residues are seen as sources of feed-stocks for energy to displace fossil fuels. A wide range of materials have been proposed for use, including grain, crop residue, cellulosic crops and various tree species. These products can be burned directly, but often are processed further to generate liquid fuels such as ethanol or diesel fuel. These fuels release CO_2 when burned, but this CO_2 is of recent atmospheric origin (via photosynthesis) and displaces CO_2 which otherwise would have come from fossil carbon. The net benefit to atmospheric CO_2, however, depends on energy used in growing and processing the bioenergy feedstock.

6.6. Communication, Education and Public awareness

Public education and outreach is a critical component of a successful implementation of climate change mitigation strategies. This effort needs to be integrated with the many public and all sectors working in energy conservation and climate change issues. Education and outreach efforts should inform the public on and create a common understanding of the science of global climate change, the potential impacts, and mitigation strategies to reduce GHG emissions including energy efficiency, alternative technologies and fuels, smart growth and natural area protection, and programs available to assist the commercial/industrial and residential sectors. The strategies that aim to educate stakeholders in all sectors and at all levels from the general public to decision makers include the following:

I. Develop and implement climate change communication, education and outreach plans to inform and engage all stakeholder in all sectors on efforts to reduce greenhouse gas emissions

II. Develop public outreach plans by sector (i.e., transportation, commercial/industrial and residential) that promote and coordinate efforts to reduce greenhouse gas emissions.

III. Seek opportunities to share information about the provincial climate change strategy and vision and identify opportunities for collaboration.

IV. Promote and support leading local businesses striving to meet energy and carbon reduction goals.

7. Climate change adaptation

Adaptation are actions initiatives and measures to reduce vulnerability of natural and human systems against actual or expected climate change effects. Adaptation measures are best implemented at policy level, which entail policy changes that enforce climate change adaptation. The adaptive capacity of a system represents the capacity of a system to adjust to climate change, including climate variability and extremes, to moderate potential damages and to take advantage of opportunities or to cope with the consequences. Adaptive capacity varies from system to system, sector to sector and region to region, and is best determined by such measures as economic standing (as already mentioned), access to technology, and access to skills and information. In that sense, communities and countries with the least resources have the least capacity to adapt and are thus the most vulnerable. The rural villages and settlements of Limpopo province are in that sense the most vulnerable due to its exposure to extreme weather events (Levey and Jury, 1996; Tennant and Hewitson, 2002; Cook et al., 2004; Thompson et al, 2012[18]). Adaptation measures must be geared to protect such vulnerable communities.

7.1. Assessing Climate Change Vulnerability

As climate change impacts become increasingly apparent in Limpopo, it is incumbent upon decision makers in the province to gain a strong comprehension of what makes a community, region, sector, or system vulnerable to climate change, the extent of such vulnerability, and then develop strategies and action plans to reduce the level and extent of vulnerability by improving the ability to cope with expected changes. This imperative is at the heart of any climate change vulnerability assessment and adaptation strategy development process. The steps involved become easier to grasp when one understands what climate change vulnerability is, and what it is comprised of.

According to the Intergovernmental Panel on Climate Change (IPCC), vulnerability to climate change can be defined as follows:

"Vulnerability is 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**."[19] (Emphasis added.)

Thus there are some critical constituent elements of climate change vulnerability, each of which has a discrete relationship with the other variables. These elements are defined differently by different sources, but at their core they can be identified as follows (largely as the IPCC does):

[18] Thompson, A.A et al 2012 Impact of Climate Change on Children's Health in Limpopo Province, South Africa. International Journal of Environmental Research and Public Health. pp 831 – 854.
[19] Intergovernmental Panel on Climate Change (IPCC), Fourth Assessment Report (2007), Report of Working Group II on Impacts, Adaptation, and Vulnerability, (Section 2.4) http://www.ipcc.ch/ipccreports/tar/wg2/index.php?idp=8

EXPOSURE

Whether a built, natural, or human system is likely (probable) to face climate change, and if so assessing the magnitude and rate of change based on future projections.

SENSITIVITY

Whether a built, natural or human system is directly or indirectly affected by or susceptible to changes in climate conditions (e.g., temperature and precipitation) or specific climate change impacts (e.g., sea level rise, increased water temperature). If a system would undergo changes as a result of climatic changes and variability, it is considered sensitive to climate change.

ADAPTIVE CAPACITY

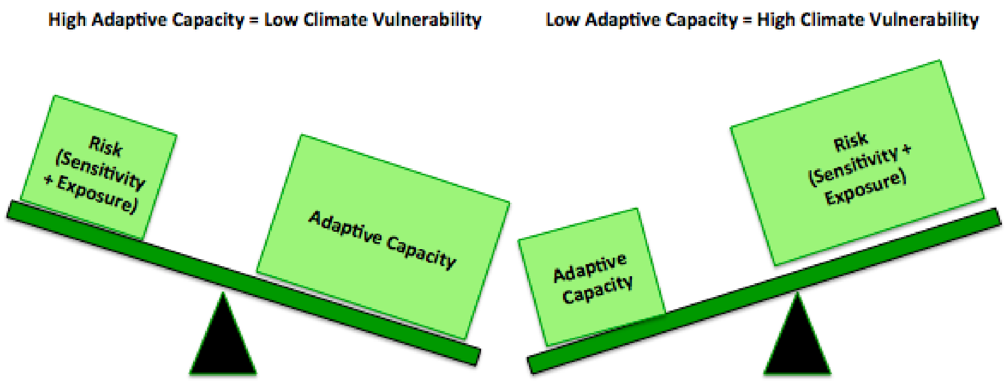
Whether a system has the ability to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

In simple terms, exposure is the extent to which a given system will be subject to or come into contact with a climate change impact – in this case, increased temperatures and changes in rainfall patterns. Sensitivity, then, is the extent to which a given system can be affected by a particular climate change impact. Sensitivity is based on inherent qualities and characteristics of an entity or system, and is an internal feature. In this case, the biophysical characteristics of the sector or sub-sector, which influence how it responds to changes in temperature or rainfall. Together, the combination of exposure and sensitivity amount to the *potential climate impact*, or "risk."

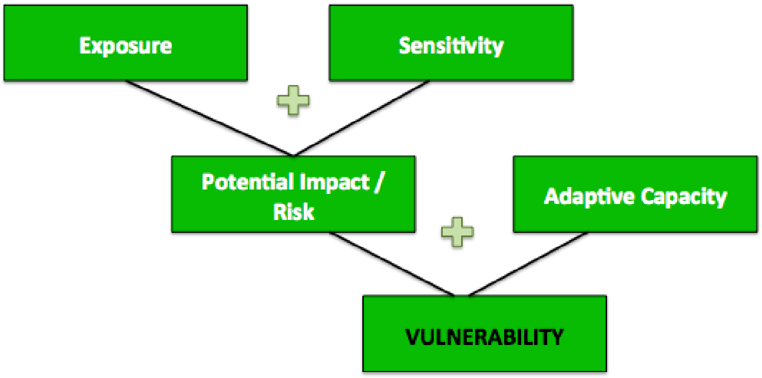
Merely because a sector or sub-sector (or any entity or system) is exposed to climate change, it does not automatically qualify as being at risk of potential impacts. If the sensitivity to climate is low, then the risk is moderated. (Similarly, if something is sensitive to changes in climate but not exposed to climate change, then risk is low as well. However, this is somewhat moot because all entities and systems on the planet are exposed to climate change – the difference is the degree to which the exposure occurs, i.e. the magnitude and rate, given that some parts of the world are warming faster than the rest or are expected to experience more significant impacts in terms of precipitation changes etc.).

In the same vein, merely because a sector or sub-sector (or any entity or system) faces a risk of climate change impacts, this does not automatically make it vulnerable. Vulnerability in the face of climate risk is also a function the entity or system's adaptive capacity. Put simply, adaptive capacity is the extent to which a system is able to exploit opportunities and resist or adjust to change. Adaptive capacity is often estimated based on proven historical ability to cope with the changes in question, and for the future it is assessed through proxies such as levels of education and income or even effective programs or policies being put in place to help the sector cope with changes in a positive manner. As the figure below illustrates,[20] the greater the adaptive capacity, the lower the vulnerability, and the lower the adaptive capacity, the greater the vulnerability.

[20] Adapted from "Adapting Urban Water Systems to Climate Change – A Handbook for Decision-makers at the Local Level," SWITCH Training Kit, 2011. As seen at Adapting to Rising Tides http://www.adaptingtorisingtides.org/vulnerability-and-risk/

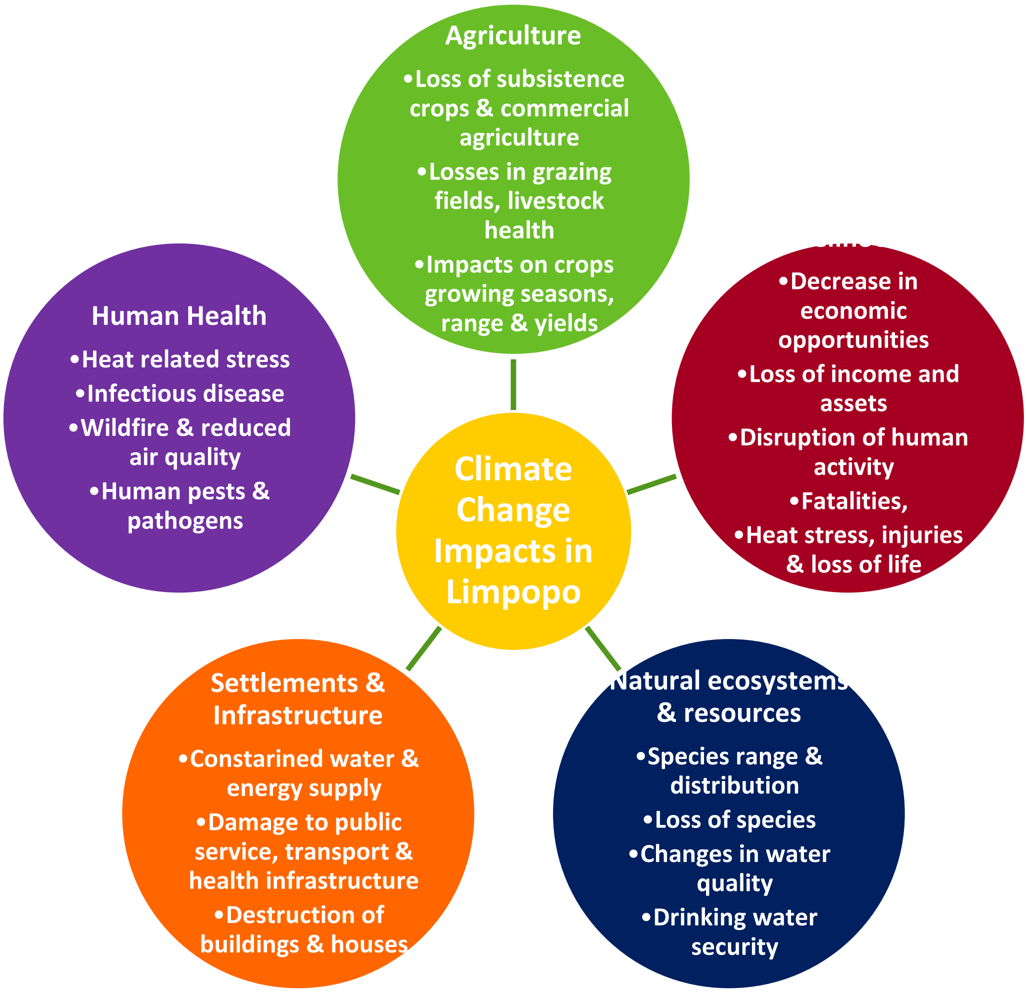


Thus, this project arrived at the determination of vulnerability of various sectors in Limpopo through the process that is typical of most climate change vulnerability assessments:



7.2. Climate Change Impacts in Limpopo

Even with greenhouse gas emission reduction efforts, Limpopo will experience impacts due to climate change, and some of these impacts are already happening at varying degrees. An investigation into climate change vulnerability in Limpopo province has highlighted specific sectors that are particularly vulnerable. The priority sectors and potential impacts identified in the vulnerability assessment report (LEDET, 2015) are summarized below:



A recent study noted with concern that even though in South Africa there is a growing body of work focusing on understanding medium to long term changes and corresponding adaptation required, "most adaptation responses still focus on reducing vulnerability to present-day climate exposure. There is little practical experience of implementing adaptation programs related to longer-term climate change"[21] . Adaptation measures are suggested for each of the identified sectors for implementation within the decade (2015 to 2025).

[21] Gina Ziervogel et al., "Climate Change Impacts and Adaptation in South Africa," WIRE's Climate Change (2014) 5:605-620. http://www.egs.uct.ac.za/downloads/Ziervogel%20et%20al%20Climate%20change%20impacts%20and%20adaptation%20in%20SA%20WIRES%20Sept%202014.pdf

8. Climate Change Adaptation Strategies

8.1. Agriculture

8.1.1. Agriculture in Limpopo

Limpopo is the breadbasket and agricultural engine of South Africa, accounting for nearly 60% of all fruit, vegetables, maize, wheat, and cotton. Livestock farming is also a significant contributor to the province's agriculture sector. It is the source of 65% of the country's papayas, 36% of its tea, 25% of its citrus fruit, bananas, and litchis, 60% of its avocados, 60% of its tomatoes (40% by one company alone), and 35% of its oranges. It produces 285,000 tons of potatoes annually.[22] An estimated 33% of households in Limpopo are considered agricultural households, and the province is home to 16% of South Africa's agricultural households.[23] Despite this, the agriculture sector contributed only three percent to the province's annual average Gross Domestic Product (GDP) in 2012.[24] Nevertheless, as noted in the Limpopo Green Economy Plan, agriculture is a key sector for the province because it is a source of food security, a contributor to exports, and an economic multiplier for the people of Limpopo through income and employment.[25]

8.1.2. Vulnerability to Climate Change

Across South Africa, climate change is expected to exacerbate already-rising irrigation demand in the agriculture sector, create spatial shifts in the growing areas for some crops, result in changes in yield for certain crops (on the balance, a fall in yields, especially in a significantly hotter future), and a shift as well as expansion in the range of several agricultural pests and parasites. Additionally, warmer temperatures are expected to increase heat stress amongst cattle, which has been linked to reduced milk yield and fertility in dairy cattle.[26]

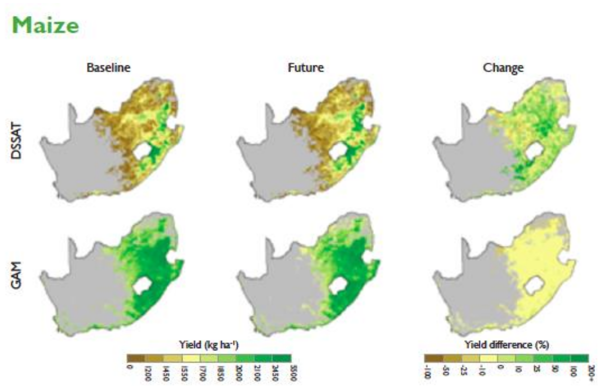


Figure 12: Median Change in Crop Yield for Rain-fed Maize

The accompanying figure is one illustration (based on two distinct models) of how yields of Maize (one of Limpopo's main crops) may be affected by climate change, with a potential range of a 25% decrease (yield loss) or even a 10% increase (yield gain).[27] There is also concern for Limpopo's citrus fruit; the temperature may become too warm for lemon cultivation, for instance.[28]

[22] GoLimpopo.Com, "Limpopo Facts Overview," last accessed May 2015. http://www.golimpopo.com/facts-overview
[23] Statistics South Africa, "A Giant Step in Agriculture Statistics," August 2013. http://www.statssa.gov.za/?p=1447
[24] Glen Steyn and Associates, "Provincial Statistical Indicators 2014," http://www.glensteyn.co.za/page/provincial-statistical-indicators-2014
[25] Limpopo Provincial Government, "Limpopo Green Economy Plan," June 2013. https://www.environment.gov.za/sites/default/files/docs/limpopogreen_economyplan.pdf
[26] Long Term Adaptation Scenarios, "Agriculture and Forestry," 2013 http://www.sanbi.org/sites/default/files/documents/documents/ltasagriculture-and-forestry-tech-report2013high-res.pdf
[27] Long Term Adaptation Scenarios, "Agriculture and Forestry," 2013 http://www.sanbi.org/sites/default/files/documents/documents/ltasagriculture-and-forestry-tech-report2013high-res.pdf
[28] Ulrike Gebhardt, "Citrus 'Superfruits' Thriving Despite Climate Change," July 2, 2013. http://www.dw.de/citrus-superfruits-thriving-despite-climate-change/a-16921898

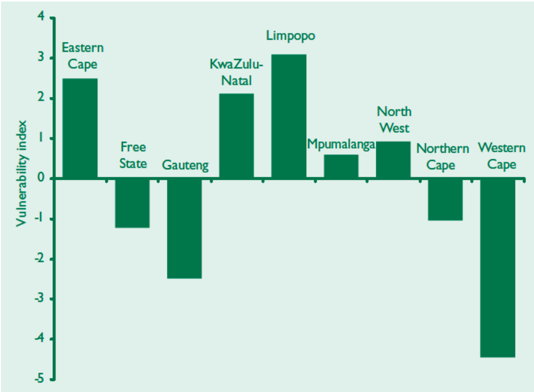


Figure 13: Climate Vulnerability of Agriculture - Ranking in South Africa by Province (Source: IFPRI)

An assessment by the International Food Policy Research Institute (IFPRI) identified Limpopo as one of South Africa's most sensitive provinces in terms of the susceptibility of the agriculture sector to climate change, mainly due to the high proportion of small-holder farmers. As indicated in the figure to the left, along with agriculture in KwaZulu-Natal and the Eastern Cape, this sector in Limpopo is expected to suffer the largest impacts of climate change and variability.[29]

8.1.3. Agricultural Adaptation in Limpopo and South Africa

The LTAS project recommends a host of adaptation practices for the agriculture sector in South Africa: (i) conservation agriculture, climate-smart agriculture, ecosystem-based adaptation, community-based adaptation, and agro-ecology; (ii) sustainable water use and management; (iii) sustainable farming systems; (iv) early warning systems, risk management and decision support tools; (v) integrated and simplified policy ad effective governance systems; and (vi) awareness, knowledge, and communications. Detailed descriptions of each may be referred to in the LTAS Agriculture report,[30] to obviate duplication of the list in this present report, whose aim is rather to identify a strategy for the province going forward.

The Limpopo Green Economy Plan similarly recommends a review of invasive species legislation, water efficiency in agriculture, the use of appropriate crops, the creation of a seed bank, companion agriculture (amongst other initiatives less salient to climate change adaptation).[31] Limpopo already has efforts underway on Conservation Agriculture (CA) under the SoilCare and LandCare programmes (in partnership between DAFF and FAO), starting with training and awareness building sessions, and evolving into longer term projects.[32]

At the national level, the Department of Agriculture, Forestry, and Fisheries (DAFF) released a Climate Change Sector Plan for Agriculture (in 2010), which identified four key performance areas (institutional arrangements; vulnerability assessments; mitigation and adaptation; response and recovery), and three critical enablers (Information management and communication; education, training, public awareness, and research; and funding arrangements). Many aspects of this plan still need to be rolled out and implemented at the provincial level.[33] Similarly, the National Climate Change Response Policy also acknowledges Climate Smart Agriculture when discussing Agriculture, Forestry, and Other Land Use (AFOLU), noting the need to, "invest in and improve research into water, nutrient and soil

[29] Glwadys Aymone Gbetibouo and Claudia Ringler, "Mapping the South African Farming Sector's Vulnerability to Climate Change and Variability – a Sub National Assessment," IFPRI Research Brief 15-3 (2009). http://www.ifpri.org/sites/default/files/publications/rb15_03.pdf
[30] Long Term Adaptation Scenarios, "Agriculture and Forestry," 2013 http://www.sanbi.org/sites/default/files/documents/documents/ltasagriculture-and-forestry-tech-report2013high-res.pdf
[31] Limpopo Provincial Government, "Limpopo Green Economy Plan," June 2013. https://www.environment.gov.za/sites/default/files/docs/limpopogreen_economyplan.pdf
[32] Pearson Mnkeni and Charlen Mutengwa, Food, Agriculture Natural Resources Policy Analysis Network, "A Comprehensive Scoping Assessment Study of Climate Smart Agriculture Policies in South Africa," April 2013. http://www.fanrpan.org/documents/d01761/South%20Africa_Comprehensive_Scoping_Assessment_of_CSA_Policies.pdf
[33] Department of Agriculture, Forestry, and Fisheries, "Climate Change Sector Plan for Agriculture," March 2010. http://www.sasscal.org/downloads/RSSC_workshop_SA_final_presentations_programme_participants_(LQ)_part_2.pdf

conservation technologies and techniques, climate-resistant crops and livestock as well as agricultural productivity in line with the National Development Plan and post 2015 Sustainable Development Goals, ownership and financing to promote the development of Climate Smart Agriculture that lowers agricultural emissions, that transitions to a low carbon sector, that is more resilient to climate change, and that boosts agricultural production." The response policy also lays out five guiding principles for the AFOLU sector, including integration with rural development, food security, and job creation; developing short term and long term land use adaptation scenarios; investing in research; investing in awareness and education programmes; and the development and use of early warning systems.[34]

A nationwide survey of farmers in South Africa indicates that several farmers have already, to varying degrees, considered and even adopted adaptation measures in response to increased climate variability. These include adjustments in farming operations (changing planting dates; adopting shorter planting periods; delaying the start of the planting period; increased use of modern machinery; collection of rainwater; increased use of irrigation; using more water-efficient crop varieties; using early-maturing varieties; and mixed farming with more livestock), increased application of chemical fertilizers and pesticides, improved water management practices, and increasing the use of shade and shelter.[35]

A survey of farmers in Limpopo reveals that farmers in the province do perceive long-term climate trends as changing, and identify certain measures as being beneficial to adapt to changing climatic conditions. For instance, fifty percent of farmers identify crop diversification as a preferred adaptation strategy. However, fewer farmers are amenable to changing current farming practices; only 15.7% were open to different planting dates, only 35% were open to planting new varieties, and 39% were open to planting different crops. Moreover, 99% of farmers surveyed were against shorter growing periods, 98% against moving to a different site, and 99% were averse to moving from farming to livestock. Sixty six percent identified increased irrigation as a suitable adaptation measure.[36] This is indicative of the challenges involved in convincing farmers to make significant changes in a system they have become used to for decades, or even generations. In the same study, farmers also identified certain barriers to adaptation – namely, lack of information, lack of government support, lack of education and skill.[37]

8.1.4. Agricultural Adaptation Lessons and Best Practices from Elsewhere

Globally as well as across Africa, there is growing momentum behind "Climate Smart Agriculture."[38] Climate Smart Agriculture is defined as involving production systems that sustainably increase productivity, resilience (adaptation), reduces or removes GHGs (mitigation), and enhances the achievement of national food security and development goals.[39] The Food and Agriculture

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[34] South African National Biodiversity Institute (SANBI) and Department of Environmental Affairs, "National Climate Change Response White Paper," (2011). http://www.sanbi.org/sites/default/files/documents/documents/national-climate-change-response-white-paper.pdf

[35] James K.A. Benhin, "Climate Change and South African Agriculture: Impacts and Adaptation Options," University of Pretoria. http://www.elsenburg.com/trd/globalwarm/downloads/agriculture.pdf

[36] Phokele Maponya and Synvester Mpandeli, "Perception of Farmers on Climate Change and Adaptation in Limpopo Province in South Africa, J Hum Ecol, 42(3): 283-288 (2013). http://www.krepublishers.com/02-Journals/JHE/JHE-42-0-000-13-Web/JHE-42-3-000-13-Abst-PDF/JHE-42-3-283-13-2381-Maponya-P/JHE-42-3-283-13-2381-Maponya-P-Tx[9].pmd.pdf

[37] Phokele Maponya and Synvester Mpandeli, "Perception of Farmers on Climate Change and Adaptation in Limpopo Province in South Africa, J Hum Ecol, 42(3): 283-288 (2013). http://www.krepublishers.com/02-Journals/JHE/JHE-42-0-000-13-Web/JHE-42-3-000-13-Abst-PDF/JHE-42-3-283-13-2381-Maponya-P/JHE-42-3-283-13-2381-Maponya-P-Tx[9].pmd.pdf

[38] The Climate Smart Agriculture Partnership, http://www.fao.org/climate-smart-agriculture/en/

[39] Climate Smart Agriculture, "About Climate Smart Agriculture," http://www.fao.org/climate-smart-agriculture/72610/en/

Organisation (FAO) has helped spur rapid uptake of Climate Smart Agriculture in different regions by providing knowledge resources and tools such as a sourcebook for implementation.[40]

In February 2014, in Tanzania, delegates from over 20 African nations attended a regional workshop on "African Agriculture in a Changing Climate – Enhancing the Uptake of Climate Smart Agriculture." They agreed that research is now increasingly pointing towards climate smart agriculture as the solution to enhancing capabilities of agricultural and food systems to cope with current climate variability in order to improve productivity and resilience.[41] Thereafter, 26 African countries have collectively launched the voluntary Climate Smart Agriculture Alliance for Africa, which aims to trigger policy changes and increase investments that strengthen African agriculture in the face of changing climate.[42] This new alliance aims to empower six million smallholder farmers across Africa by the year 2021, and is launching its first stage of efforts in Zambia, Ethiopia, and Niger.[43]

There are emerging success stories and best practices for Climate Smart Agriculture from various parts of Africa. For instance, potato farmers in Tanzania are expecting a harvest with ten times the average yield.[44] Traditional "Kihamba" agro-forestry techniques in Tanzania are helping raise incomes by an estimates 25%. Small holder farmers in Kenya and Tanzania are adopting water and soil conservation practices. Zambia and Malawi are strengthening their institutional and policy capacity to support climate smart agriculture. Farmers in Rwanda have increased income through agricultural diversification and mixed farming.[45]

Thus, adopting some of the tenets and practices of Climate Smart Agriculture, as locally applicable and adaptable, may be of relevance for provinces in South Africa such as Limpopo.

8.1.5. Climate Adaptation Measures for Agriculture in Limpopo - Recommendations

There is still a dearth of province-specific scientific literature on climate change impacts on the agricultural sector and on locally relevant climate change adaptation practices. While there is awareness of Climate Smart Agriculture and agricultural climate resilience more generally amongst responsible institutions, officials, and even some farmers within Limpopo, available literature points to the province being at early stages of engaging with and operationalizing such efforts.

The recommendations that follow are closely linked to the concepts of Climate Smart Agriculture, but the specifics of these adaptation strategies have been suggested by stakeholders in Limpopo bearing in mind overall sustainability of the agriculture sector as well. The original adaptation strategies were presented to stakeholders in a provincial workshop in May 2015 and the experts present there reformulated and modified the recommended strategies into the following:

[40] Food and Agricultural Organisation (FAO), "Climate Smart Agriculture for Development," http://www.fao.org/climatechange/climatesmart/en/
[41] CGIAR Research Program on Climate Change, Agriculture, and Food Security, "Building Climate Resilience in the African Agricultural Sector," February 26, 2014. http://ccafs.cgiar.org/blog/building-climate-resilience-african-agriculture-sector#.VUMxFEsaWs1
[42] CGIAR Research Program on Climate Change, Agriculture, and Food Security, "A Climate-Smart Agriculture Alliance for Africa," June 15, 2014. http://ccafs.cgiar.org/blog/climate-smart-agriculture-alliance-africa#.VUMtrUsaWs0
[43] Africa CSA http://africacsa.org/#founding-members
[44] CGIAR Research Program on Climate Change, Agriculture, and Food Security, "In Pictures: Ten-Fold Potato Yield in Lushoto, Tanzania," April 13, 2015. http://ccafs.cgiar.org/blog/pictures-tenfold-potato-yield-lushoto-tanzania#.VUMy3EsaWs0
[45] FAO, "Success Stories on Climate Smart Agriculture," 2014. http://www.fao.org/3/a-i3817e.pdf

I. **Create a Climate Smart Agriculture programme to help develop or promote the use of specific seed or plant varieties in specific locations:** There is a fair amount of agro-climatic diversity even within Limpopo province. Thus, an applied research program that spurs the development or adoption of specific varieties of climate-resilient seeds or plants should aim to identify different varieties for different parts of the province. This should take into account different soil types, different staple food and dietary patterns, and other such local constraints and preferences. Such a program should involve field trials and other on-the-ground initiatives and train farmers to use these new, locally suited varieties.

II. **Enhance ongoing efforts involving Conservation Agriculture:** the province is already engaged in great depth with Conservation Agriculture. These activities should be given a boost and such programs expanded and provided greater resources. Sub-programs should be developed and expanded to focus on key components such as mulching, agroforestry, livestock, mixed farming, nutrient conservation, water conservation etc.). These programs should involve a research component to generate much more locally relevant data, and the studies could be carried out by agricultural research centers within the province (e.g. universities) or external experts, or in partnership, and in many cases would include local trials and field tests. But the programs would also involve skills building and knowledge transfer activities to train farmers and build on-farm capacity.

III. **Initiate a dedicated climate change adaptation programme for cattle ranching / livestock rearing in the province:** A multi-year, province-specific programme should be launched to help livestock farmers and cattle ranchers adapt to changing climatic conditions. Given the predominance of cattle farming in the province, this is a key area for intervention. Such a campaign would include the production of greater research conducted within the province, with results relevant to the local industry, but also include applied research on adaptation measures. It would involve education and training sessions, funding for on-farm adaptation measures, and ongoing assistance to ensure that farmers are maximizing the benefits of the adaptation responses utilized.

IV. **Fund and implement a comprehensive climate change awareness and skills-building programme within the province:** such an awareness-building programme would be broad based and far-reaching in nature. Its design would include new curriculum (or additions to curriculum) in schools and colleges (in both basic and higher education), to teach students earlier about climate change impacts on agriculture as well as adaptation measures. It would also involve the generation of knowledge materials that could be widely disseminated, especially at key events such as Earth Day, World Environment Day, Arbor Day etc. The programme would also include awareness generation through the use of radio and television and other media, to increase public knowledge of climate change's impacts on agriculture and potential adaptation responses. The programme would not be tailored only towards the public, but would also target farmers themselves, and would involve educational outreach about the impacts of climate change on the specific crops grown in specific areas; it would engage farmers on various practices that can strengthen climate resilience (in an effort to lower their resistance to change) on their own land, and train them on best practices (to enhance their ability to reap successful results from adaptation measures).

All of the aforementioned programs could be designed and developed in a one-year timeframe and then implemented on an ongoing, continuous basis (with periodic review and evaluation and recalibration as needed). Funding could be sought from development partners and by seeking grants, but would also be secured from the national treasury. The lead implementation entity would be the Department of Agriculture, Forestry and Fisheries (DAFF), working in close collaboration with the Department of Environmental Affairs (DEA), Limpopo Department of Agriculture (LDA), Department of Water and Sanitation (DWS), and Department of Education.

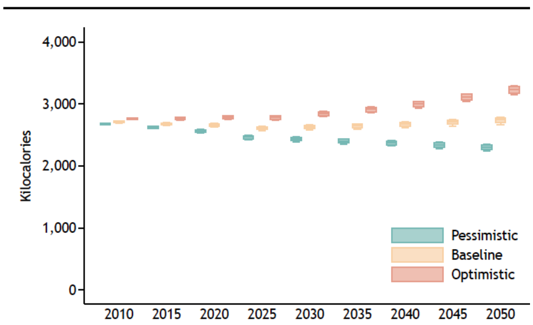
8.2. Livelihoods and Settlements – Rural and Urban

8.2.1. Livelihoods and Settlements in Limpopo

The relatively high vulnerability of rural livelihoods – predominantly based on agriculture and livestock – is a matter of significance for Limpopo province, which is home to South Africa's largest land area with rural inhabitants, mostly relying on natural resources for subsistence. Of all of South Africa's provinces, Limpopo had the lowest per capita income (annual), as recorded in the 2011 census.[46] While the urban population in Limpopo is relatively small compared to the rural population, stakeholders at the provincial workshop in May 2015 noted that in the future, with more rural-urban migration, the balance would shift, and emphasized that the adaptation strategies in this report should also apply to the urban setting.

8.2.2. Vulnerability to Climate Change

South Africa-wide projections suggest that in a pessimistic (high-emissions) scenario, climate change will have an impact on the number of kilocalories available for consumption per capita, causing 20% slight decline by mid-century, primarily due to a decrease in agricultural yield. This is also expected to spark an initial increase (through 2025) in the number and percentage of malnourished children under five years.[47]



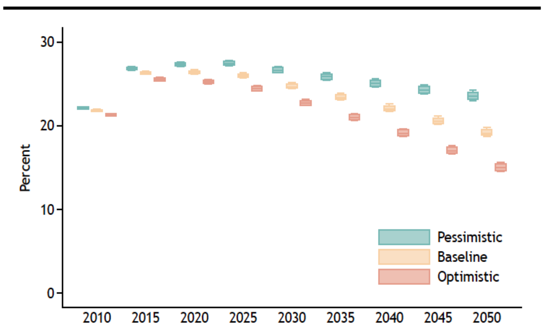


Figure 14a: Kilocalories per capita in South Africa in multiple income and climate scenarios (2010-2050); and Figure 3b: Share of malnourished children under five years of age in South Africa in multiple income and climate scenarios (2010-2050). (Source: IFPRI).

[46] South Africa Statistics, "Census 2011," published 2012. http://www.statssa.gov.za/publications/P03014/P030142011.pdf
[47] Peter Johnston et al., IFPRI, "South Africa – Chapter 7," in Southern African Agriculture and Climate Change, 2013. http://www.ifpri.org/publication/southern-african-agriculture-and-climate-change

Impacts from climate variability, such a drought, are already a problem for livelihoods in Limpopo and are likely to become more pronounced with climate change. For instance, one study found that food security in Limpopo is negatively impacted by drought, resulting in food scarcity, and that farmers have already had to sell their livestock to cope with reduced availability and higher prices of livestock feed during drought.[48] While the impact of this is greatest in rural areas, ripple effects would be felt in urban areas, which source their food from rural regions of the province.

In general, resource-poor settings such as Limpopo are at a greater disadvantage in coping with the effects of climate change and adapting to changing conditions. Limpopo's climate vulnerability in terms of livelihoods is as much a function of expected climate impacts as it is a function of high levels of poverty and unemployment, dependence on agriculture for food security and employment, and inadequate access to sanitation, water supply, and healthcare.[49]

Within such settings, it is often the extremely young and the extremely old (i.e. children and the elderly, who are not part of the formal working population) who face the biggest challenges coping with climatic changes and the resultant impact on household livelihoods. Limpopo, together with KwaZulu-Natal and the Eastern Cape, accounts for 76% of all rural dwelling children. Additionally, 78.7% of children in Limpopo are estimated to live below the poverty line.[50] The age distribution of Limpopo's population is also shifting towards older age groups: in 2001, 52.2% of the provincial population was 19 years old or younger, while in 2011, this group dropped to 45.6%. At the same time, the population aged from 20 to 64 years comprised 42.1% of the total in 2001, but increased to 48.2% of the total in 2011. Now there are also more people aged 65 years older, from 5.7% of the total in 2001 to 6.3% of the total in 2011.[51] In 2011, Limpopo had the highest proportion of elderly people who classify as poor, at 77%.[52] These trends are also likely to continue, implying an increase in the number and share of Limpopo's population that is more vulnerable to climate change impacts, particularly livelihoods (since they are often a dependent population not generating their own livelihoods).

Limpopo also has amongst the highest rates of out-migration of all of South Africa's provinces,[53] which is often indicative of the more able-bodied individuals (with higher abilities to cope with change) leaving the province and a disproportionate share of those remaining in the province being those will relatively lower adaptive capacity.

8.2.3. Rural and Urban Livelihoods Adaptation in Limpopo and South Africa

Given the predominance of agriculture as a source of subsistence and food security in Limpopo, adaptation to a changing climate on livelihoods is, to a significant degree, agricultural adaptation.

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[48] Phokele Maponya and Sylvester Mpandeli, "Impact of Drought on Food Scarcity in Limpopo Province, South Africa," African Journal of Agricultural Research Vol. 7(37), pp. 5270-5277, 25 September, 2012. http://www.academicjournals.org/article/article1380886085_Maponya%20%20and%20Mpandeli.pdf

[49] UNICEF, "Exploring the Impact of Climate Change on Children in South Africa," 2011. http://www.unicef.org/southafrica/SAF_resources_climatechange.pdf

[50] UNICEF, "Exploring the Impact of Climate Change on Children in South Africa," 2011. http://www.unicef.org/southafrica/SAF_resources_climatechange.pdf

[51] Glen Steyn and Associates, " Provincial Statistical Indicators, 2014." http://www.glensteyn.co.za/page/provincial-statistical-indicators-2014

[52] Statistics South Africa, "Profile of Older Persons in South Africa," 2011. http://www.statssa.gov.za/publications/Report-03-01-60/Report-03-01-602011.pdf

[53] South Africa Statistics, "Census 2011," published 2012. http://www.statssa.gov.za/publications/P03014/P030142011.pdf

Literature indicated that some farmers in Limpopo province have been experimenting with climate adaptation measures such as modifying their planting dates, increasing their irrigation potential, and changing the amount of land used for cultivation.[54] One study in Limpopo (in Vhembe district) found that some farmers in the area do already use adaptive strategies to make agriculture more resilient to climate change and variability. For instance, they have already turned to drought-resistant varieties, crop diversification, planting more water-efficient crops or crops that require less water on the whole, adjusting fertilizer input, using rainwater harvesting techniques, and even monitoring local weather indicators.[55] Significantly, another study found that merely providing farmers information about drought does not strengthen their resilience to it, and has no positive correlation to the farmers experiencing food scarcity.[56] This implies that along with improving access to credible climate change and variability information, there is a need for more rigorous and involved training for farmers on how to use the available information optimally.

There are also several one-off examples in Limpopo to turn to for lessons on how small holder farmers are creating sustainable livelihoods for themselves – for instance, improved yields demonstrated by Mercy Sithagu of Sithagu Farms;[57] self-learning through community solidarity based farming associations in Nwadjahane and Khomele;[58] and diversification and value-addition demonstrated by the biodiesel non-profit Mapfura-Makhura Incubator.[59]

At the national level, the National Climate Change Response Strategy White Paper suggests the following adaptation responses for rural human settlements: supporting small-scale farmers including on-farm demonstration and experimentation related to conservation agriculture; empowering local communities – especially women – to design and implement adaptation strategies; designing and implementing economic diversification; prioritizing adaptation technologies such as low water-use irrigation, water harvesting, and drought-resistant seed varieties; and enhancing disaster-management architecture in rural areas.[60] It also makes note of the need to overcome apartheid-era spatial planning challenges through land redistribution without compromising on food security and agricultural production.

For urban settlements, increased temperatures in built areas (i.e. the Urban Heat Island Effect) are likely to be a key impact on both settlements and livelihoods (since heat affects labor productivity and health). This is particularly a concern for informal settlements and shacks in peri-urban areas, where there are limited resources and people travel longer distances in heat. While there isn't much documented information about green design, green roofs, and other climate adaptation measures in

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[54] UNICEF, "Exploring the Impact of Climate Change on Children in South Africa," 2011. http://www.unicef.org/southafrica/SAF_resources_climatechange.pdf
[55] Sylvester Mpandeli, "Managing Climate Risks Using Seasonal Forecast Information in Vhembe District in Limpopo Province," Journal of Sustainable Development , Vol. 7, No. 5 , October 2014. https://www.questia.com/library/journal/1P3-3443567481/managing-climate-risks-using-seasonal-climate-forecast
[56] Phokele Maponya and Sylvester Mpandeli, "Impact of Drought on Food Scarcity in Limpopo Province, South Africa," African Journal of Agricultural Research Vol. 7(37), pp. 5270-5277, 25 September, 2012. http://www.academicjournals.org/article/article1380886085_Maponya%20%20and%20Mpandeli.pdf
[57] Tarryn Genis, "South African Farming Entrepreneur Builds Sustainable Livelihood," *The Guardian,* 2012. http://www.theguardian.com/sustainable-business/south-africa-farming-entrepreneur
[58] Osbahr, H., C. Twyman, W. N. Adger, and D. S. G. Thomas. 2010. Evaluating successful livelihood adaptation to climate variability and change in southern Africa. *Ecology and Society* **15**(2): 27 http://www.ecologyandsociety.org/vol15/iss2/art27/
[59] Agnes Musyoki, UNRISD, "The Emerging Policy for Green Economy and Social Development in Limpopo, South Africa," June 2012. http://www.fes-globalization.org/geneva/documents/8%20UNRISD%20Musyoki.pdf
[60] South African National Biodiversity Institute (SANBI) and Department of Environmental Affairs, "National Climate Change Response White Paper," (2011). http://www.sanbi.org/sites/default/files/documents/documents/national-climate-change-response-white-paper.pdf

urban areas in Limpopo, there are indications that some innovative work has been gaining traction in relation to school buildings and the momentum is likely continuing with green design elements of commercial and government buildings.[61]

8.2.4. Livelihoods Adaptation Lessons and Best Practices from Elsewhere

The UK-funded Western Odisha Rural Livelihoods Project in India offers some valuable insights, given the many demographic and development parallels between the province (state) of Odisha in India and Limpopo province in South Africa. The project focused on building overall resilience amongst rural communities by: "(i) building structures and processes that develop community skills and confidence, enabling them to articulate their needs and demand improved services; (ii) enabling the poor and marginalized to become actively and effectively involved in planning and development; (iii) promoting equity between socio-cultural groups and empowering rural women; (iv) promoting farm and non-farm enterprises that improve income, employment and nutritional security, relieve the debt burden, and encourage savings; (v) improving management of common property and the fair distribution of its benefits; (vi) promoting local technology that responds to specific needs, including the particular

needs of women; (vii) helping communities and local service providers – government or non-government - to use modern participatory methods for planning, implementation, monitoring and evaluation; and (viii) helping to create an environment that promotes pro-poor policy change."[62] Even though the core focus of this program was not on climate change adaptation per se, the results indicate that the communities involved in the project are now better able to respond to climate variability, in terms of both droughts and heavy rainfall. The success also led to uptake of this approach by the state government.[63]

Other best practices and viable case studies to draw lessons from include the World Food Program's (WFP) Managing Environmental Resources to Enable Transitions to More Sustainable Livelihoods (MERET) project, which has worked with over 500 communities in Ethiopia to enhance livelihood resilience to weather-related shocks, and improving food security, by rehabilitating land and water resources;[64] the Food and Agriculture Organization's (FAO) demonstrations of 15 viable agricultural adaptation practices in Bangladesh, geared towards drought mitigation, climate resilience, economic robustness, increased production, sustainability and social acceptability, where communities self-selected the use of mini-ponds, homestead gardens, dry seedbeds for rice cultivation, and cultivating hardy species of trees as their preferred adaptation options amongst the over 225 activities demonstrated and tested;[65] and Malawi's Climate Adaptation for Rural Livelihoods and Agriculture

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[61] Holcim Foundation, "A Big Tick from Educationalists and Green Architects," July 15, 2013. http://www.holcimfoundation.org/Article/a-big-tick-from-educationalists-and-green-architects
[62] DDInternational, "Western Odisha Rural Livelihoods Project," http://ddinternational.org.uk/viewProject?project=4
[63] Virinder Sharma et al., "Sustainable Rural Livelihoods Approach for Climate Change Adaptation in Western Odisha, Eastern India," *Development in Practice* Volume 24, Issue 4 (2014). http://www.tandfonline.com/doi/abs/10.1080/09614524.2014.911817?journalCode=cdip20
[64] Inter Agency Standing Committee (IASC), "Addressing the Humanitarian Challenges of Climate Change – Regional and National Perspectives: Case Studies on Climate Change Adaptation," 2009.
[65] Inter Agency Standing Committee (IASC), "Addressing the Humanitarian Challenges of Climate Change – Regional and National Perspectives: Case Studies on Climate Change Adaptation," 2009.

(CARLA) project,[66] which is partially underway but has begun offering key implementation lessons about capacity building and training.[67]

8.2.5. Climate Adaptation Measures for Livelihoods and Settlements in Limpopo - Recommendations

Since the majority of livelihoods in Limpopo province are very closely tied to agriculture, the recommended adaptation measures for that sector would also be beneficial for livelihoods. In addition, however, a few other key interventions are recommended, particularly with a view to economic diversification. Limpopo must actively explore how to provide alternative means of livelihoods to its people, divorced from agriculture. Furthermore, stakeholders in Limpopo province also underscored the need for adaptation strategies that address physical safety, i.e. flood risk. The recommendations below are those that were put forward to stakeholders in the provincial workshop in May 2015, were evaluated by those in attendance and revised and reframed as follows:

I. **Devote resources to identifying and providing training on alternate sources of livelihood for different regions and communities within Limpopo.** The provincial government should establish an applied research programme that makes a rigorous analysis of viable alternative means of livelihood for different communities in different parts of Limpopo, based on locally available resources, existing and potentially transferable skill-sets, and the needs and aspirations of the communities concerned. Once some viable alternatives have been determined (in the 1-2 year timeframe), the program should transition into a 2-3 year technical training and skills-building program involving demonstration projects to help the communities' uptake of the alternative livelihood sources. This program could be done in collaboration with universities, research institutes, development partners, but most importantly it should be grounded within the communities and be co-designed and co-implemented by the communities in collaboration with external and government experts. Given the small share of agriculture in Limpopo's GDP, the introduction and adoption of alternative means of livelihoods may bring more value-addition into the provincial economy and generate more income for the communities and the province as a whole, while also potentially arresting the out-migration (which is motivated by a search for opportunities outside the province).

II. **Create and strengthen support business development mechanisms for smallholder farmers.** The province of Limpopo, in partnership with the national government (Department of Rural Development and Land Reform), with development institutions and donors, and the private sector, should enhance opportunities for rural communities in Limpopo (especially farmers) to develop sustainable livelihoods. This entails raising credit availability through loans, grants, and microfinance; increasing access to and participation in markets; and institutional resources in the form of sustainable rural livelihoods board or committee that can offer

[66] AfDB, "CARLA Project Appraisal Report," October 2011. http://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/Malawi_-_AR_-_Climate_Adaptation_for_Rural_Livelihood_and_Agricuture__CARLA__-_LOTB_-_Approved_.pdf

[67] UNDP, National Adaptation Plan Global Support Programme, "Reporting, Monitoring and Review: Experiences and Lessons Learnt from National Climate Change Programme and NAPA Implementation in Malawi," April 2014. http://www.undp-alm.org/sites/default/files/malawi_nap-gsp_africa_regional_training_workshop_element_d_malawi.pdf

guidance and feedback to rural communities in order to help them identify and develop new opportunities in the agricultural value chain.

III. **Redouble efforts to improve overall socio-economic security and wellbeing**. Climate change resilience is in part a function of existing human vulnerability and adaptive capacity, which are influenced by several overarching socio-economic factors. In Limpopo province, adaptive capacity in livelihoods will automatically be strengthened with broad-based development and inclusive economic growth. As a corollary, no amount of sector-specific climate adaptation strategies and plans will bring about long-lived resilience unless they are built on a foundation of economic and social security. Thus, even from a climate change adaptation point of view, the province of Limpopo must redouble and accelerate its efforts to extend the coverage of safe drinking water supply, adequate sanitation, adequate and reliable electricity supply, formal housing, education, and access to healthcare services. In doing so, it must integrate climate change into its existing plans and policies, so as to ensure climate mainstreaming within broader development programmes and initiatives. It could also align its own targets more closely with the post 2015 Sustainable Development Goals, and thereby leverage available international support for the achievement of SDGs.

IV. **Enhance efforts to reduce flood risk to rural and urban communities:** Physical safety of both rural and urban settlements should be improved by reducing and managing flood risk. Limpopo has been prone to flooding in several recent years, and climate change is likely to exacerbate the treat. Better land use management needs to be implemented, taking current as well as future flood risk into account. This should be supplemented with an education and training program to help build capacity in communities to respond to floods; this can include training in the use of sandbags or building levees. More Early Warning Systems should be put in place, but the systems could be technological as well as based on indigenous approaches and people’s networks. Municipalities need to invest in more effective and higher capacity storm water draining systems; these can reduce the impact of floods.

Each of the aforementioned initiatives could be developed (or further strengthened, building on existing efforts) in a one-year timeframe and then implemented on an ongoing, continuous basis (with periodic review and evaluation and recalibration as needed). These strategies should all be integrated into the municipal Integrated Development Plans (IDPs). Responsibility for implementation would rest with DAFF and the Department of Rural Development and Land Reform (DRDLR) for the first three adaptation strategies suggested above, and with DWS and the Department of Public Works (DPW) for the fourth. Close inter department coordination is key to effective implementation and results for these strategies. Funding could be secured from development partner, but would also be sought from the national treasury.

8.3. Terrestrial and Aquatic Ecosystems

8.3.1. Terrestrial and Aquatic Ecosystems in Limpopo

Ecosystems in Limpopo, both terrestrial and aquatic, are highly vulnerable to climate change impacts, particularly in the longer term. Given the large number of people who depend on natural resources for their livelihoods, this is a threat both to human populations as well as the biodiversity of Limpopo's ecosystems. Preserving Limpopo's ecosystems in the face of climate change pressures is key, especially in light of the Limpopo Green Economy Plan's emphasis on utilizing unexploited biodiversity resources in the province for green tourism and payments for ecosystem services.[68]

According to the South African National Biodiversity Institute, Limpopo Province already has one critically endangered ecosystem (Woodbush granite grassland), five endangered ecosystems (Blouberg forest, Malmani karstlands, Mapungubwe/Greefswald riverine forest, Sekhukhune mountain lands, and Sekhukhune bushveld), and four vulnerable ecosystems (Legogote sour bushveld, Lowveld riverine forest, Springbokvlakte thornveld, and Tzaneen sour bushveld).[69]

8.3.2. Vulnerability to Climate Change

Most of Limpopo falls within the Savanna biome, and the Savanna ecosystem has a fairly high resilience to climate variability and change. Thus it is considered less vulnerable than many other ecosystems.[70] Grasslands are less prevalent in Limpopo but the grassland zone that does exist (primarily in the southern/central parts of the province) are at risk from climate change, with an increased likelihood that warmer temperatures and higher carbon dioxide levels in the atmosphere will support the growth of wooded plants and trees, edging out grasses. The savanna biome is likely to shift into areas currently covered by grasslands, with species currently present at higher elevations replaced by species from lower elevations, which move up with warmer temperatures. This could substantially change vegetation in Kruger National Park, for instance, with implications for wildlife in the area.[71]

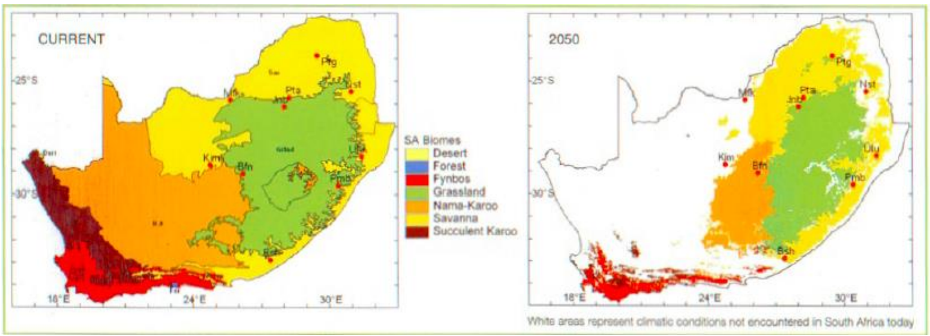

Figure 4: Biomes of South Africa as Mapped in 2000 and Projected in 2050 (Source: SANBI, The Heat is On)

[68] Limpopo Provincial Government, "Limpopo Green Economy Plan," June 2013. http://www.thehda.co.za/uploads/images/HDA_Limpopo_Report_lr.pdf
[69] South African National Biodiversity Institute, "Summary of Listed Ecosystems by Province," http://bgis.sanbi.org/ecosystems/Summary_%20listed_ecosystems_province.pdf
[70] CSIR, Risk and Vulnerability Atlas, "Information Portal K2C," http://www.rvatlas.org/k2c/information/conservation.php
[71] South African National Biodiversity Institute, "The Heat is On," 2008 http://www.sanbi.org/sites/default/files/documents/documents/theheatison.pdf

However, there is also growing evidence to suggest that the Savanna biome itself may face negative impacts from climate change, as a result of encroachment by bush and woody tree vegetation.[72] This type of forest encroachment (or forest colonization), is more likely in a wetter climate scenario, with more rain; while Limpopo is likely to see an increase in rainfall volume and more heavy rainfall events, rising temperatures and evaporation are also likely to lead to an overall drier climate in the region, leaving it unclear whether Limpopo's savannas may be encroached on by forest ecosystems.[73] A better understanding is required of the impact of changing climatic conditions (carbon dioxide levels, temperature, rainfall, evaporation) in conjunction with non-climate factors (fire, grazing, changes in local megafauna etc.) on different types of savanna ecosystems in South Africa (for instance, the varied response between mesic and semi-arid savanna).[74]

Similarly, aquatic ecosystems in an already water-stressed province are likely to be negatively impacted by warmer temperatures and greater evaporation rates. Water use and availability in the Limpopo basin will be discussed more in the next section (the water sector) but several studies point to a decrease in water availability and decreased rainfall for the river basin, with implications for river-based biodiversity.[75] Invasive species are also a concern for aquatic ecosystems in Limpopo province.

According to findings from the LTAS project, Limpopo is in the zone within Northeast South Africa (mainly the Limpopo river basin), which is likely to experience a "substantial risk" for loss of bird species richness.[76]

8.3.3. Ecosystem Adaptation in Limpopo and South Africa

Limpopo's Green Economy Plan identifies key priority areas for action on biodiversity and ecosystem management. These include the Limpopo Biodiversity Conservation Plan, valuation of natural resources, the up-scaling of existing programs under the "working for" umbrella (with a focus on removing alien plants and maintaining the veld), production of final products and beneficiation from natural resources, tree planting etc.[77]

The Limpopo Biodiversity Conservation Plan is a systematic guidance for conservation in Limpopo province, comprising maps of Critical Biodiversity Areas (CBAs) and land-use guidelines. Through this comprehensive process, nearly 40% of the province has now been identified as CBAs, with another 22% classified as Ecological Support Areas.[78] While the plan was created taking into account climate change (for instance through the integration of "Ecosystem Based Adaptation" areas that specifically

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[72] Vhalinavo P. Khavaghali and William J. Bond, "Increase of Woody Plants in Savannah Ecosystems," Grassroots – Newsletter of the Grassland Society of South Africa, Vol. 8, No. 2 (May 2008). http://grassland.org.za/resources/grassroots/2006-to-2010/2008/May%202008/5%20Khavhagali%20May%202008.pdf
[73] Robert J. Scholes, "Impacts and Adaptations to Climate Change in the Biodiversity Sector in Southern Africa," AIACC Project Number AF04, Final Report (2006). http://www.start.org/Projects/AIACC_Project/Final%20Reports/Final%20Reports/FinalRept_AIACC_AF04.pdf
[74] R. Buitenwerf et al., "Increased Tree Densities in South African Savannas: >50 Years of Data Suggests CO2 as Driver," Global Change Biology (2011). http://researchspace.csir.co.za/dspace/bitstream/10204/6127/1/Stevens_2012.pdf
[75] Tingju Zhu and Claudia Ringler, "Climate Change Implications for Water Availability in the Limpopo River Basin," IFPRI Discussion Paper 00961 (April 2010). http://www.ifpri.org/sites/default/files/publications/ifpridp00961.pdf
[76] Department of Environmental Affairs, Long Term Adaptation Scenarios, "Biodiversity," 2013. http://www.sanbi.org/sites/default/files/documents/documents/ltasbiodiversity-tech-report2013high-res.pdf
[77] Limpopo Provincial Government, "Limpopo Green Economy Plan," June 2013. https://www.environment.gov.za/sites/default/files/docs/limpopogreen_economyplan.pdf
[78] SANBI, "Limpopo Conversation Plan V.2," Technical Report, 2013. http://bgis.sanbi.org/limpopo/LCPv2_technicalReport_hires.pdf

support climate change resilience, and targets for conservation in the EBAs), the plan cannot be viewed as a climate change adaptation plan for ecosystems in Limpopo province.

A helpful tool that is available to Limpopo is the SANBI-developed Biodiversity GIS Land Use Decision Support (LUDS) tool, which provides municipality-level biodiversity information and summaries, enabling planners to better understand the impacts of land use decisions on underlying ecosystems.[79] However, this too does not integrate information about projected climate change impacts to ecosystems and recommended adaptation measures.

The National Climate Change Response Strategy White Paper notes, in relation to biodiversity and ecosystem adaptation to climate change, that responses to climate change should include the following: (i) strengthening biodiversity management and research institutions for better monitoring and assessment; (ii) conservation, rehabilitation, and restoration of natural ecosystems that improve resilience; (iii) prioritizing impact assessment and adaptation planning; (iv) prioritizing research into climate change ecosystem threats in marine and terrestrial ecosystems, including effective monitoring; (v) expanding the protected area network with a perspective on climate resilience; (vi) encouraging partnerships for areas that are not under formal protected status; and (vii) expanding gene banks.[80]

8.3.4. Ecosystem Adaptation Lessons and Best Practices from Elsewhere

In recent years there has been growing interest in and uptake of Ecosystem Based Adaptation (EBA), which brings together traditional biodiversity conservation, socio-economic development, and climate change adaptation. The key elements of EBA are Community-Based Natural Resource Management (CBNRM), Community Based Adaptation (CBA), and Climate Change-Integrated Conservation Strategies.[81]

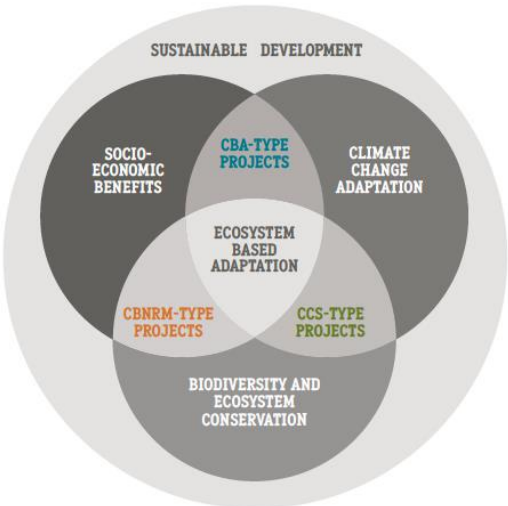

Figure 5: Ecosystem Based Adaptation

There are several examples of positive results from EBA in the field. These include IUCN's efforts in Zambia, Tanzania, and Mozambique (emphasizing the role of forests and water resources in community livelihoods), community-based fire management in Northern Australia (West Arnhem),[82] the government of Colombia's efforts to work with local communities to build climate resilience through the protection of thousands of hectares of tropical ecosystems rich in medicinal plants,[83] debt-for-nature swaps funded by France that involve local communities in

[79] SANBI, Biodiversity GIS, "Municipal LUDS," http://bgis.sanbi.org/municipalities/choose-muni.asp?prov=LIM
[80] South African National Biodiversity Institute (SANBI) and Department of Environmental Affairs, "National Climate Change Response White Paper," (2011). http://www.sanbi.org/sites/default/files/documents/documents/national-climate-change-response-white-paper.pdf
[81] SANBI, "Biodiversity, Climate Change, and Sustainable Development," http://www.sanbi.org/sites/default/files/documents/documents/biodiversity-climate-change-and-sustainable-development_0.pdf
[82] IUCN, "Ecosystem Based Adaptation – A Natural Response to Climate Change," 2009. https://cmsdata.iucn.org/downloads/iucn_eba_brochure.pdf
[83] UNFCCC, "Ecosystem Based Adaptation," 2012 Calendar. https://unfccc.int/files/adaptation/application/pdf/nwp_cal_2012.pdf

Madagascar and Cameroon,[84] grassland protection and restoration in China by the Gansu and Xinjiang Pastoral Development Project,[85] and sustainable pasture management in Mongolia to protect grasslands as well as livelihoods of local herders.[86] One of the richest sources of information in the realm of freshwater ecosystem adaptation is the World Bank's 'Flowing Forward' report, which takes a biodiversity lens to water resources management in a changing climate.[87]

There is also a great deal of literature (including case studies) about ecosystem conservation (particularly aquatic ecosystems) through the removal and management of Alien Invasive Species.[88]

8.3.5. Climate Adaptation Measures for Ecosystems in Limpopo - Recommendations

In the context of the well renowned tourism sector of Limpopo Province, biodiversity represents a valuable asset that could be tapped into to facilitate economic development and creation of betterment opportunities. The potential effects of climate change on biodiversity in Limpopo are minimal and may result in stimulation of tree growth and bush encroachment into open grassland areas. Densification of savannas and predicted drier conditions in savannas/rangelands may result in an increased fire danger. Through suitable mitigation measures, such fire risks can be contained. The other impacts on biodiversity are fairly minimal and it is argued that woodlands possess sufficient adaptive capacity to contain these impacts.

Across South Africa and Limpopo, a significant amount of attention and resources are already devoted to conservation and ecosystem preservation. However, there appears to be a need for both (a) focused programmes and initiatives that specifically take a climate change perspective when examining ecosystems (terrestrial and aquatic); and (b) further integrating climate change into existing plans, policies, and programs, i.e. climate mainstreaming in conservation and natural resources management. To this end, a few key recommendations are offered:

I. **Develop a specialized climate change management programme to focus on protection of Limpopo's two main terrestrial ecosystems in the face of climate change:** There is a credible evidence-base to indicate that climate change is likely to have deleterious impacts on the grassland ecosystems in Limpopo, and potentially also on the savanna ecosystem. However, in addition to better understanding the climate and non-climatic dynamics that result in change, it is also essential to develop more robust studies about the biodiversity, natural capital, and human livelihoods impacts of these changes, as well as what can be done to reduce or better manage the change. Thus Limpopo could consider establishing, in partnership with other South African provinces that share grassland and savanna ecosystems,

[84] Tahia Devisscher, "Ecosystem Based Adaptation in Africa," Stockholm Environmental Institute 2010. http://www.unep.org/climatechange/adaptation/Portals/133/documents/AdaptCost/10%20EBA_AdaptCost_Final.pdf
[85] The World Bank, "Convenient Solutions to an Inconvenient Truth: Ecosystem Based Approaches to Climate Change," June 2009. http://siteresources.worldbank.org/ENVIRONMENT/Resources/ESW_EcosystemBasedApp.pdf
[86] Asian Development Bank, "Making Grasslands Sustainable in Mongolia: Adapting to Climate and Environmental Change," February 2014. http://www.adb.org/publications/making-grasslands-sustainable-mongolia-adapting-climate-and-environmental-change
[87] Tom Le Quesne et al., "Freshwater Ecosystem Adaptation to Climate Change in Water Resources Management and Biodiversity Conservation," November 2010. http://www.flowingforward.org/pdf/full.pdf
[88] Jenny Davis et al., National Climate Change Adaptation Research Facility, Australia, "Climate Change Adaptation Guidelines for Arid Zone Aquatic Ecosystems and Freshwater Biodiversity," February 2013. http://www.nccarf.edu.au/sites/default/files/attached_files_publications/Davis_2013_Climate_change_adaptation_guidelines_for_arid_zone.pdf

and the South African National Biodiversity Institute, a dedicated programme that strengthens the understanding of climatic changes to the two ecosystems, and simultaneously increases the knowledge-base regarding the socio-economic implications of such changes. This applied research programme could then, in conjunction with development partners, fund and implement conservation programs to arrest or manage the impacts of climate change in certain regions covered by the two ecosystems (such as in sub-sections of already protected areas).

II. **Identify and integrate specific climate-change related priorities and metrics when next revising the Limpopo Biodiversity Conservation Plan:** given the role of the Limpopo Biodiversity Conservation Plan in ecosystem and natural resource management in the province, it is a critical vehicle within which to embed climate change adaptation. When the plan is next revised, the latest-available research on climate change management in grassland and savanna ecosystems should inform the plan's revision (including within its quantitative targets and metrics), so as to strengthen the plan's ability to promote climate change adaptation and resilience within Limpopo's two primary ecosystems.

III. **Formally establish and draw resources to a scientific research project to better understand the loss of bird species-richness in the South African Limpopo Basin:** The LTAS project is unequivocal about the loss of bird species richness in the Limpopo basin in Northeast South Africa, resulting from climate change. However, publically available literature does not reflect a wealth of information on this topic, suggesting that there is a need for filling the gaps with greater research. Across the world, there is a notable constituency of persons and institutions that are dedicated to the protection and well-being of birds, and would be strong allies for an effort to strengthen research on which birds are most at risk in the area, and what potential adaptation measures and conservation interventions could provide them support. Thus it may be viable to establish a programme focusing on the impacts of climate change on avian life in the relevant region, partnering with groups such as BirdLife International, Audubon, and other bird conservancies.

IV. **Develop a focused climate change adaptation response plan and implementation programme targeting the province's wetlands and water pans:** Aquatic and freshwater ecosystems are often neglected in favor of terrestrial ecosystems (including flora and fauna). Publicly available literature does not demonstrate that a lot of attention has been given to studying the impacts of climate change on wetlands and water pans in Limpopo province, and the resulting impacts on surrounding ecosystems from changes to wetlands. Wetlands are key locales for biodiversity and play a critical role in ecosystem functioning as well as the provision of ecosystem services. Thus, to better understand the implications for Limpopo and to build resilience, a dedicated programme should be launched to closely study the impacts of climate change in the province, and to implement pilot adaptation measures based on best practices in wetland conservation.

Strategies I, III, and IV (suggested above) involve programmes that could be designed and developed in a one-year timeframe and then implemented on an ongoing, continuous basis (with periodic review and evaluation and recalibration as needed). If ongoing, continuous implementation is challenging due to limited resources, the programs should be run for at least two to three years in a pilot phase and then re-evaluated for longer-term continuation. For these programmes, the primary implementation responsibility would fall on DEA, in close collaboration with the Limpopo Department of Economic Development, Environment, and Tourism (LEDET). For Strategy II, LEDET would be the lead implementation entity (specifically, the Biodiversity Directorate). The national Treasury would be the primary source of funding, but development partners and international conservation groups such as IUCN (and Birdlife International or Audubon for Strategy III) could be approached for assistance.

8.4. Water Supply

8.4.1. Water Supply in Limpopo

Access to freshwater, which is already a major challenge in Limpopo, is predicted to become a much bigger problem under climate change, with potentially devastating effects on sectors such as agriculture, human livelihoods, and the industrial and mining sectors. The water resources in Limpopo have already been fully allocated and there is no surplus water available for reallocation to other uses. The only options available are through reallocation from existing users to others as part of the water reallocation programme, or through employing innovative options such as efficiency in the use of the resource or use of treated water and recycling. This would serve to optimise the amount of the water resource that is available for allocation and improve the production levels of sectors like agriculture. Economic development is on the whole dependent on water supply, so containing the effects of climate change on water availability is all the more important.

Limpopo predominantly depends on surface water resources, and has relatively limited groundwater aquifers due to the geological nature of the province (despite this, groundwater is a significant source of water for domestic use in rural areas). According to the 2011 census, only 52.3% of Limpopo's population had access to piped water supply within their own dwelling or yard (and 14% of the population has no access to piped water at all).[89] Nearly a quarter million people and an estimated 300 schools had no access to any formal water infrastructure, as of 2010.[90] Irrigation accounts for an estimated 53% of water use in Limpopo, while rural water services account for less than five percent of available water resources (the mining and power sector account for eight percent each).[91]

Nearly all of Limpopo's Municipal Water Services Authorities (WSAs) were deemed as highly or very highly vulnerable, according to the Department of Water Affairs, in 2013 (on a general, non-climate basis).[92] Similarly, the Limpopo Green Economy Plan notes that of Limpopo's 19 Water Management Areas, five already experience water shortages, and that several more could face shortages by 2025.[93]

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[89] South Africa Statistics, "Census 2011," published 2012. http://www.statssa.gov.za/publications/P03014/P030142011.pdf
[90] Limpopo Department of Public Works, "Strategic Plan 2010-2015," http://www.dpw.limpopo.gov.za/docs/publications/StrategicPlan2010-2015.pdf
[91] Limpopo Water Sector Strategy and Five Year Plan (2006). https://www.dwaf.gov.za/Masibambane/documents/strategies/pwsp/lp/limpopo-strategy.pdf
[92] Department of Water Affairs, "Strategic Overview of the Water Sector in South Africa, 2013," http://nepadwatercoe.org/wp-content/uploads/Strategic-Overview-of-the-Water-Sector-in-South-Africa-2013.pdf
[93] Limpopo Provincial Government, "Limpopo Green Economy Plan," June 2013. https://www.environment.gov.za/sites/default/files/docs/limpopogreen_economyplan.pdf

At the basin level (not just Limpopo province), within South Africa the waters of the Limpopo river are used mainly for agricultural use (62%), followed by industrial use (21%), and then domestic use (17%).[94]

8.4.2. Vulnerability to Climate Change

Studies indicate that in most climate change scenarios projected for the Limpopo river basin in South Africa, future water supply availability by 2050 will "worsen considerably."[95] For a province that is heavily agrarian (with significant irrigation needs), as well as a province where nearly 48% of the population did not have access to piped water within their own dwelling or yard (in 2011), the prospects of increased water stress are significant.

For the Northeastern region of South Africa (including Limpopo), climate change is likely to pose the following risks to the water sector:[96]

- Decreased availability of water in rivers as a result of the net effect of increased temperatures and increased evaporation, combined with shifts in the timing and amount of rainfall;
- Changes in the timing of high and low flows due to changes in rainfall patterns;
- A higher incidence of floods as heavy rainfall events increase;
- Increased risk of water pollution and decreased water quality, arising from erosion and high rainfall events (which elevate the amount of nutrient runoff, sediments, and dissolved organic carbon) and increased temperatures (which promote algal blooms).

Greater rainfall intensity in this region is expected to increase scouring in rivers and sedimentation in dams, which has implications for water treatment and supply infrastructure.[97]. Projections suggest that even without the exacerbating influence of climate change, South Africa will "exceed the limits of economically viable land-based water resources by 2050," making this sector highly vulnerable to climate stressors.[98]

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[94] Berhanu F Alemau, FARNPAN, "Limpopo River Basin Focal Project – Water Availability and Access," 2008. http://www.fanrpan.org/documents/d00554/LBFP_water_availability_literature_Jul2008.pdf

[95] Tingju Zhu and Claudia Ringler, IFPRI, "Climate Change Impacts on Water Availability and Use in the Limpopo River Basin," Water 2012, 4, 63-84; doi:10.3390/w4010063

[96] Claire Davis, CSIR, "Climate Change Handbook for Northeastern South Africa," 2010. http://www.rvatlas.org/k2c/download/handbook_climate_change.pdf

[97] South African National Biodiversity Institute (SANBI) and Department of Environmental Affairs, "National Climate Change Response White Paper," (2011). http://www.sanbi.org/sites/default/files/documents/documents/national-climate-change-response-white-paper.pdf

[98] South African National Biodiversity Institute (SANBI) and Department of Environmental Affairs, "National Climate Change Response White Paper," (2011). http://www.sanbi.org/sites/default/files/documents/documents/national-climate-change-response-white-paper.pdf

8.4.3. Water Supply Adaptation in Limpopo and South Africa

Experts suggest that future climate change related water stress in the Limpopo basin in South Africa can be potentially mitigated by improved water infrastructure and management, although it will be difficult to compensate for all the adverse impacts.[99]

The Limpopo Green Economy Plan identifies several priorities for water resources management moving forward, including: facilitating water security by creating awareness; greater water use efficiency in the mining sector; alternative water storage; water recycling; improved reticulation; water harvesting; reduced household consumption; catchment management; and regulation of swimming pools.[100]

At the national level, the South Africa Risk and Vulnerability Atlas points to Integrated Water Resource Management (IWRM) as a framework for improving socio-economic welfare of people dependent on water resources without compromising the sustainability of ecosystems. It also emphasizes that water adaptation in South Africa requires more investment in information, stronger institutions, and man-made water adaptation infrastructure.[101]

The National Climate Change Response Strategy White Paper recommends a host of adaptation approaches for the water sector: (i) integrating climate change in planning processes across various relevant sectors; (ii) sustaining state of the art research on water and climate change; (iii) transboundary water management with a regional perspective; (iv) investing in water conservation and demand management, and the best catchment management; (v) exploring new or un-used sources of water such as groundwater, desalination, and treated re-usable effluents; (vi) increasing community water resilience; (vii) providing human, legal, regulatory, institutional, governance, and financial resources to cope with climate change in the water sector; and (viii) undertaking focused monitoring and research.[102]

The LTAS water sector report outlines adaptation responses across several areas, ranging from institutional approaches to hard infrastructure and service delivery, i.e. water resources management, water resources infrastructure, and water services. In particular, it underscores the need to integrate adaptation into water resources planning frameworks in South Africa, and incorporate climate change adaptation into reconciliation studies. It also reaffirms measures highlighted in the water sector climate change adaptation strategy, including water governance; infrastructure development, operation, and maintenance; and water management (which incorporates resource management and protection; gathering and storing of better reported water data; water planning; water allocation and authorization; optimization of dam and groundwater management and operation; water conservation and demand management; and disaster management).[103]

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[99] Tingju Zhu and Claudia Ringler, "Climate Change Implications for Water Resources in the Limpopo River Basin," IFPRI Discussion Paper 00961 (April 2010). http://www.ifpri.org/sites/default/files/publications/ifpridp00961.pdf

[100] Limpopo Provincial Government, "Limpopo Green Economy Plan," June 2013. https://www.environment.gov.za/sites/default/files/docs/limpopogreen_economyplan.pdf

[101] Department of Science and Technology, "South African Risk and Vulnerability Atlas," 2010 http://www.rvatlas.org/download/sarva_atlas.pdf

[102] South African National Biodiversity Institute (SANBI) and Department of Environmental Affairs, "National Climate Change Response White Paper," (2011). http://www.sanbi.org/sites/default/files/documents/documents/national-climate-change-response-white-paper.pdf

[103] South African National Biodiversity Institute (SANBI), Long Term Adaptation Scenarios, "Water," 2013. http://www.sanbi.org/sites/default/files/documents/documents/ltaswater-tech-report2013high-res.pdf

8.4.4. Water Supply Adaptation Lessons and Best Practices from Elsewhere

There is a wealth of information on water sector adaptation measures and best practices from various corners of the globe. What is less clear, given the complexity of water resources and water supply systems, is the extent to which the range of measures adopted have been successful and to what degree. Nevertheless, there are lessons to draw from the activities taking place in this sector the world over.

Canada's Adaptation to Climate Team (ACT)'s policy roadmap for decision makers on climate change adaptation is instructive for water governance.[104] Burkina Faso's experience with the United Nations' national adaptation planning process is a demonstration of how well established institutional arrangements can foster early strategic thinking about medium and long term adaptation strategies.[105] The United Nations' Environment Programme (UNEP) has resources on eleven key water technologies that aid adaptation, with illustrative information on where they've been used successfully to build adaptive capacity, including developing countries like India (the technologies include boreholes and tube-wells; desalination; household drinking water treatment and storage; protected wells; leakage management and detection systems for piped water; post-construction support for community-managed water supplies; rainwater collection; rainwater harvesting; water reclamation and re-use; and water safety plans).[106]

The Alliance for Global Water Adaptation (AGWA) is a helpful network and resource on the integration of climate change adaptation approaches into water infrastructure development, with projects around the world to draw insights from.[107]

8.4.5. Climate Adaptation Measures for Water Supply in Limpopo - Recommendations

Given the critical nature of water resources to human and economic wellbeing, there has been considerable work done on developing water-sector climate change adaptation strategies at the global, regional, and national levels. Relative to some other sectors, this is a sector that is well studied and receives a fair amount of attention from governments, development agencies and international institutions. Thus there is a rich body of knowledge to draw from for water sector planners and practitioners when evolving climate change adaptation strategies for Limpopo province. Some common themes reappear frequently across much of this literature, emphasizing the type of adaptation measures or approaches that are recognized widely as being integral to building resilience in the water sector: water management or governance, water infrastructure, and water service delivery. Thus, the recommendations here are also a reflection of those tenets, familiar to all in the water sector in South Africa, but with a need to now operationalize them in a province-specific manner.

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[104] Bon Sandford et al., "Briefing Paper for Decision Makers: Climate Change Adaptation and Water Governance," 2011. http://www.gwp.org/Global/ToolBox/References/Climate%20change%20adaptation%20and%20water%20governance%20(ACT-SFU,%202011).pdf

[105] UNFCCC, LDC Expert Group, "Best Practices and Lessons Learnt in Addressing Adaptation in the Least Developed Countries Through the National Adaptation Program of Action Process." 2011. http://www.gwp.org/Global/ToolBox/References/Best%20practices%20and%20lessons%20learned%20in%20addressing%20adaptation%20in%20the%20least%20developed%20countries%20(UNFCCC,%202011).pdf

[106] Mark Elliott et al., UNEP, "Technologies for Climate Change Adaptation – The Water Sector," April 2011. http://www.gwp.org/Global/ToolBox/References/Technologies%20and%20Practices%20for%20Climate%20Change%20Adaptation%20in%20the%20Water%20Sector%20(UNEP,%202011).pdf

[107] Alliance for Global Water Adaptation, http://alliance4water.org

I. **Establish a cross-sectoral, inter-departmental governance framework to help integrate and mainstream climate change adaptation into all water related operations.** Water is a cross-cutting issue such that optimal management – whether in the present of for the future, taking into account climate change – cannot be done in isolation by one department. In order to ensure that climate change adaptation is integrated in all major water resource decisions and is reflected in actual implementation, there needs to be coordination between those responsible for agriculture and irrigation, for industry, for public works and domestic water supply and sanitation, for disaster management, forestry and land use, and public health. Thus, at the province level, Limpopo should establish a governance framework or mechanism (such as a standing committee or advisory board) with membership reflecting decision makers across all relevant sectors, with a specific mandate to think about and suggest how climate change adaptation can be integrated into various existing water related processes, policies, instruments, and programmes, in a holistic and well-coordinated way to ensure sectoral alignment.

II. **Ensure that proposed water related infrastructure projects explicitly integrate climate change resilience into their planning and design stages.** Limpopo is already a water-stressed environment, and increasing variability with climate change is expected to exacerbate the situation. Even as there may be more heavy rainfall events, there will likely be a rise in evaporation, creating greater challenges for water availability for all users. There are several plans and proposals underway to develop water-related infrastructure for Limpopo (such as water storage for supply, advanced water treatment plants, or flood risk reduction structures etc.), and more are likely to emerge as development pressures in Limpopo increase. Any such proposed project must integrate climate change considerations into the entire project development process, including in the design, planning, pre-feasibility and feasibility stages, to ensure that such infrastructure projects are effective in a non-stationary environment that be modified by climate change. The role of strong and effective infrastructure in the water sector cannot be overstated. Thus, efforts to maintain and repair infrastructure should also be ramped up, and an adaptation plan should be developed to address how Limpopo intends to safeguard and maintain its water infrastructure in the face of more climatic stressors like droughts, heavy rains, and floods.

III. **Raise performance and efficiency of water service delivery for domestic use, with aggressive quantitative targets.** A key determinant of overall human vulnerability is access to basic services. Limpopo province has a lot of ground to cover in terms to providing people adequate access to safe and reliable drinking water for domestic consumption, cooking, bathing etc. Until such time that the population universally enjoys water security, strengthening climate change resilience through other adaptation measures in this or other sectors will be significantly more challenging. Thus, Limpopo should set or strengthen targets for provision of universal access (in line with national targets or even more ambitious) and quantitative, measurable metrics for performance and efficiency (such as the reduction of conveyance losses from leaks). These should be annually evaluated and recalibrated based on progress made. One of the performance metrics suggested by stakeholders is the number of water engineers and technical staff in the eater sector trained to understand the impacts of climate change on this sector, so that they can be better prepared.

IV. **Strengthen existing Catchment Management efforts:** Adaptation to climate change in the water sector must go beyond water infrastructure and institutional arrangements, to the source of the water itself. Thus, there is a need to enhance Catchment Management activities already underway in the province. Specifically, efforts should be made to stem and reduce deforestation in catchment areas (as well as degradation). Attention should also be given to the removal of alien invasive species in catchments.

All the strategies articulated above could be developed (or further strengthened, building on existing efforts) in a one-year timeframe and then implemented on an ongoing, continuous basis (with periodic review and evaluation and recalibration as needed). These strategies should all be integrated into the municipal Integrated Development Plans (IDPs). Responsibility for implementation would rest with the Department of Water and Sanitation (DWS). However, very close coordination and cooperative governance approaches would be required, involving DEA, DAFF, DRDLR, DPW, the Department of Mineral Resources (DMR) and the Department of Cooperative Governance and Traditional Affairs (CoGTA). The national Treasury would be the main source of funding, with allocations in Departmental budgets.

8.5. Human Health

8.5.1. Human Health in Limpopo

Limpopo's population has lower life expectancy – 54 years – than the national (57 years) and global average (71 years).[108] In terms of rural health capacity (including number of practitioners and healthcare facilities in relation to the disease burden, as well as general indicators such as lack of access to piped water or toilet facilities etc.), one study identifies Greater Sekhukhune district as one of the ten most "deprived" districts in South Africa.[109] According to one estimate, poor rural households in some Limpopo districts spend as much as 80 percent of their monthly income on health expenditure (predominantly transportation costs to seek healthcare).[110]

One of the biggest healthcare challenges in the province is the continued prevalence of HIV/AIDS, which has taken a considerable toll on the working-age population of Limpopo. In contrast, the province is performing much better in combating tuberculosis (TB), and is estimated to have the second best cure rate in the country.[111] However, neither HIV/AIDS nor TB is linked to climatic factors and thus climate change has no implications for their prevalence. In this context, it is Limpopo's second, third, fourth, fifth, and sixth leading causes of death that could potentially be exacerbated by climate change: hypertensive heart disease, diarrhea, lower respiratory infection, stroke, and ischemic heart disease respectively.[112]

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[108] DBSA, "Limpopo Profile Summary Report," 2012. http://www.dbsa.org/EN/DBSA-Operations/Proj/Documents/Summary%20of%20Limpopo%20Province.pdf
[109] Rural Health Advocacy Project, "Fact Sheet Rural Health – November 2013," http://www.health-e.org.za/wp-content/uploads/2014/02/Updated-Rural-Fact-Sheet-27-Nov-2013.pdf
[110] Rural Health Advocacy Project, "Fact Sheet Rural Health – November 2013," http://www.health-e.org.za/wp-content/uploads/2014/02/Updated-Rural-Fact-Sheet-27-Nov-2013.pdf
[111] Health Systems Trust, "Limpopo Province," http://www.hst.org.za/uploads/files/secB_lp.pdf
[112] Debbie Bradshaw et al., South African National Burden of Disease Study, "Estimates of Provincial Mortality: Limpopo Province," 2000. http://www.mrc.ac.za/bod/limpopo.pdf

Most significantly, Limpopo is a region of moderate to high malaria risk (especially the eastern regions of the province),[113] and climate change has significant implications for the spread of malaria as well as other similar vector-borne diseases. Malaria outbreaks in Limpopo are not uncommon, as was seen recently in the summer of 2014.[114]

8.5.2. Vulnerability to Climate Change

Populations in Limpopo are vulnerable to the impacts of climate change, at least partly as a result of overall low health indices and diminished adaptive capacity. This is a result of the disease burden from HIV/AIDS, and tuberculosis, as well as poor nutritional status.

In terms of vulnerability to climate change related health impacts, Limpopo is also more sensitive, relative to some other provinces. Temperatures in Limpopo, especially the interiors, are likely to be warmer than some of South Africa's coastal regions. Additionally, due to the number of informal settlements (inadequate shelter) and the demographic trend of older populations (more elderly as a proportion of the population), the province is particularly susceptible to heat related health impacts such as heat stroke, dehydration, diarrheal disease, and mortality and morbidity from chronic disease (respiratory and cardiac, in particular) that is exacerbated by thermal stress on the body (from the body having to work harder physiologically to maintain thermal equilibrium).

One of the few studies to have specifically looked at the impact of climate change on human health in Limpopo focused on the effects on children. The study found that climatic factors such as increasing temperatures affected the incidence of several diseases amongst children in Limpopo province, including diarrhea, respiratory disease, asthma, and malaria, and that climatic factors could be responsible for as much as 37% of the total disease burden.[115]

Overall, at the national level, the Department of Health's National Climate Change and Health Adaptation Plan defines nine areas of health risk that are likely to be impacted by climate change: heat stress; vector-borne diseases; malaria; food insecurity, hunger, and malnutrition; natural disasters; air pollution; communicable diseases (like cholera); non-communicable diseases; mental health; and occupational health.[116]

8.5.3. Human Health Adaptation in Limpopo and South Africa

The only significant study to address climate change in the health sector in Limpopo is one that was focused on children. However, many of the study's recommendations are applicable to the health sector across the board in terms of building adaptive capacity and stronger responses to climate related health concerns. Some of these recommendations include: an awareness raising and educational campaign, to inform families of the risks to health from high temperatures and changing vector habitats; improving overall socio-economic status of households in Limpopo, to ensure better nutrition and level of health; reduction of populations living in poorly-serviced high density rural settlements; improved sanitation and waste collection services by the municipality, including in

[113] SA Venues, "Malaria Risk Areas in South Africa," http://www.sa-venues.com/malaria-risk-areas.htm
[114] eNCA, "Malaria Outbreak in Limpopo," March 29, 2014. http://www.enca.com/south-africa/malaria-outbreak-limpopo
[115] Adeboyejo Aina Thompson et al., "Impact of Climate Change on Children's Health in Limpopo Province, South Africa," Int J Environ Res Public Health. 2012 Mar; 9(3): 831–854. Published online 2012 Mar 8. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3367281/
[116] Long Term Adaptation Scenarios, SANBI, "Health," 2013. http://www.sanbi.org/sites/default/files/documents/documents/ltashuman-health-tech-report2013high-res.pdf

informal settlements; and reduction of deforestation and preservation of tree cover for shade (and to reduce the risk of erosion and flooding), amongst others.[117]

South Africa's National Climate Change Response Strategy White Paper highlights several adaptation responses for the health sector. These include the following: (i) reducing air pollution and diminishing other contributors to respiratory disease; (ii) improving food security and nutritional status; (iii) developing and rolling out public awareness campaigns on the health risks of heat and to inculcate avoidance behaviors; (iv) designing and implementing heat-health action plans, including improved climate-sensitive disease surveillance; (v) strengthening information base through research; (vi) improving health-data capturing such that it can be linked into multiple-risk systems like the SARVA database; (vii) improving the malaria control strategy to reduce its bio-safety hazards (from DDT); and (viii) strengthening awareness about malaria and cholera outbreaks.

In addition to these, the LTAS project identifies other key interventions necessary for the health sector, including more vulnerability assessments; enhanced monitoring and surveillance; improved access to data; multi-sectoral collaboration; and strengthening individual and social adaptive capacity overall.[118]

8.5.4. Human Health Adaptation Lessons and Best Practices from Elsewhere

Prestigious medical and health journal The Lancet has identified climate change as potentially being the biggest public health threat of the twenty first century.[119] The Intergovernmental Panel on Climate Change (IPCC) has also highlighted human health as one of the key areas of climate change impact, and emphasized the need for climate change adaptation in the health sector.[120] The IPCC's discussion of adaptation in the healthcare sector includes early warning systems, seasonal forecast systems, public education and awareness campaigns, improvement in national and international disease surveillance, the use of earth observation systems (remote sensing satellite data and Geographic Information Systems), and better training of health care professionals with regard to the effects of climate change.

The World Health Organisation (WHO) has started providing guidance to countries on how to include adaptation measures for the health sector in the process of developing National Adaptation Plans (as part of a country's submissions to the UNFCCC). The WHO's guidance urges countries to have national level climate change health adaptation strategies and to put in place adequate institutional arrangements to address climate change in the health sector.[121] The European Union is also working to increase climate change adaptation in the health sector. In its draft strategy document on adaptation to climate change impacts on human, plant, and animal health, the EU emphasizes awareness raising and communication, better inter-governmental and inter-agency cooperation,

[117] Adeboyejo Aina Thompson et al., "Impact of Climate Change on Children's Health in Limpopo Province, South Africa," Int J Environ Res Public Health. 2012 Mar; 9(3): 831–854. Published online 2012 Mar 8. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3367281/

[118] Long Term Adaptation Scenarios, SANBI, "Health," 2013. http://www.sanbi.org/sites/default/files/documents/documents/ltashuman-health-tech-report2013high-res.pdf

[119] The Lancet, Editorial, "Managing the Health Effects of Climate Change," May 13, 2009. http://www.thelancet.com/commissions/climate-change

[120] IPCC, Fourth Assessment Report, Report of Working Group II on Impacts, Adaptation, and Vulnerability, "Human Health," Chapter 8, 2007. https://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch8.html

[121] WHO, "WHO Guidance to Protect Health from Climate Change Through Health Adaptation Planning," 2014. http://apps.who.int/iris/bitstream/10665/137383/1/9789241508001_eng.pdf?ua=1

cross-sectoral policies, and the use of preparedness and risk management systems such as the EU's 'Climate, Environment, and Health Action Plan and Information System (CEHAPIS).[122]

A host of other resources also exist, showcasing best practices and lessons learned, for health care professionals and health sector policymakers[123] concerned with increasing adaptive capacity or resilience to climate change.[124] The majority of these include recurring themes such as improving the ability of surveillance systems to detect trends triggered by climate change, making infectious disease surveillance systems especially comprehensive, implementing heat early warning systems, increasing public awareness of the health impacts of climate change, and enhancing knowledge and training of health care professionals to equip them to better anticipate and address climate change related health impacts.[125]

Increasingly, coalitions and associations of medical practitioners and other health care professionals are also joining forces to urge adaptation and resilience-building in the health sector, as a response to climate change. These organizations can be useful resources to their counterparts in South Africa. A few examples include Healthcare Without Harm,[126] the Climate and Health Council,[127] and Physicians for Social Responsibility.[128]

8.5.5. Climate Adaptation Measures for Human Health in Limpopo - Recommendations

Globally the health sector has received an increasing amount of attention in recent years, in the context of climate change impacts to human health and the development of adaptation responses to ameliorate and manage such impacts. In South Africa, however, there is comparatively less literature on this subject, due to fewer health sector studies that specifically take a climate change perspective. While the field is certainly growing and is better understood every passing day, there is still a pressing need for credible, peer reviewed literature from within South Africa and from within Limpopo province to shed light on various aspects of the public health threats from climate change. Thus, the following recommendations are made with a view to strengthening this body of evidence and building capacity in the health sector to cope better with expected impacts from climate change.

I. **Formally join, participate in, and leverage capacity and information from global climate change health networks and knowledge-sharing platforms.** Globally, there is an extraordinary wealth of information on climate change impacts on the health sector. Limpopo can benefit from this rich evidence base by establishing partnerships and collaborations with some of the leading institutions working in this space (universities and medical research organizations), as well as networks of practitioners who are actively implementing climate change adaptation strategies in the health sector in similar settings.

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122 European Commission, "Adaptation to Climate Change Impacts on Human, Animal, and Plant Health," Commission Staff Working Document, 2013. http://ec.europa.eu/clima/policies/adaptation/what/docs/swd_2013_136_en.pdf
123 Anthony McMichael, NCCARF, "Human Health," 2009. https://www.nccarf.edu.au/sites/default/files/attached_files_publications/NCCARF%20health%20brochure_S.pdf
124 Emma Back, CDKN, "Managing Climate Extremes and Disasters in the Health Sector," 2012. http://cdkn.org/wp-content/uploads/2012/10/SREX-lessons-for-health-sector.pdf
125 Jonathan Samet, Resources for the Future, "Public Health: Adapting to Climate Change," March 2010. http://www.rff.org/RFF/Documents/RFF-IB-10-06.pdf
126 Healthcare Without Harm https://noharm.org
127 The Climate and Health Council http://www.climateandhealth.org
128 Physicians for Social Responsibility http://www.psr.org/environment-and-health/climate-change/

II. **Secure, dedicate, and allocate substantial funding for better climate-related health surveillance and monitoring in the province and to carry out studies within Limpopo on health impacts of climate change**. Within South Africa and especially within Limpopo province, there is still a dearth of locally-relevant medical and public health literature that can inform decision makers about specific threats within Limpopo, and the best measures to tackle the specific risks. This type of evidence base can be built and strengthened by both improving disease surveillance and monitoring systems (and to make them more attuned to climate-sensitive diseases), and by funding more research that investigates climate related health impacts and trends in the province (this research will, in turn, benefit from the enhanced monitoring and data-collection).

III. **Fund and implement a comprehensive public health and climate change awareness and adaptive capacity building programme,** with a particular focus on heat-health and vector-borne diseases, water-borne diseases, respiratory health, and with a special focus on vulnerable populations like children and the elderly. While there is a large range of health impacts that are likely to be influenced and exacerbated by climate change, adaptive capacity can be strengthened fairly quickly in the short term by focusing on some of the more well-understood diseases and health impacts that are of greater relevance in a setting like Limpopo. Even as the healthcare sector's own capacity must be raised to respond better to climate-related health impacts, there are significant gains to be made be empowering people (especially women and families) to monitor their own health and take adaptive measures to reduce their risk in simple ways. Thus, an educational and capacity-building campaign would be of benefit in Limpopo.

IV. **Redouble efforts to improve overall socio-economic status and health indices:** As is the case with livelihoods, vulnerability of the health sector to the impacts of climate change would be reduced by enhancing overall levels of population health. Healthier communities have more adaptive capacity and are more resilient to risks such as heat waves or lowered water quality (due to higher immune status). Nutritional status must be elevated and under-nutrition or malnutrition minimized. Thus, even from a health sector climate change adaptation perspective, socio-economic factors must be taken into account and the overall well-being of Limpopo's residents must be improved. This calls for greater successes in the implementation of existing economic development programmes, greater access to essential services like water supply and electricity, and more capacity in the health sector (more health care providers, shorter distances to seek assistance etc.). Sanitation in particular must be a priority, and Limpopo must extend coverage of population with access to adequate sanitation. Better systems should be put in place for waste disposal and collection from informal settlements and shacks. Thus at the broadest level possible the province must integrate climate change into its existing socio economic and health plans and policies, so as to ensure climate mainstreaming within broader development programmes and initiatives. The achievement of these, in turn, will make the health of Limpopo's people stronger and better prepared to cope with health stressors driven by climate change.

Each of the aforementioned initiatives could be developed (or further strengthened, building on existing efforts) in a one-year timeframe and then implemented on an ongoing, continuous basis (with periodic review and evaluation and recalibration as needed). These strategies should all be integrated into the municipal Integrated Development Plans (IDPs). Responsibility for implementation would rest the Department of Health, but in coordination with LEDET, DWS, DEA, and the Department of Education (DoE). Funding could be secured from development partners and international institutions (given a large potential pool of health sector grants and aid), but would also be sought from the national treasury.

9. Conclusion

It is critical that the recommended mitigation and adaptation strategies in this report not become relegated to archival documentation but that they are translated into implementable and actionable adaptation plans.

For the strategies to be converted into ground reality, it is imperative that the relevant provincial departments for each sector within the province take cognizance of the recommended strategies, and integrate the strategies into their annual planning and budgetary processes. Departments are best placed to assess the yearly and long-term expenditure required for the application of such strategies, and have a detailed understanding of their funding streams. Thus, sector-experts within the provincial departments should be given the responsibility of preparing detailed implementation plans for the relevant strategies, identifying timelines, coordination mechanisms, monitoring and evaluation mechanisms, metrics to gauge the implementation and progress of the strategy, and the required financial and human resources.

In addition, the national Department of Environmental Affairs (DEA), the Department of Agriculture, Forestry and Fisheries (DAFF), the Department of Human Settlements (DHS), the Department of Water and Sanitation (DWS), the Department of Mineral Resources (DMR), the Department of Energy (DOE), the Department of Rural Development and Land Reform (DRDLR), and the Department of Tourism are urged to take note of the sector-by-sector strategies recommended for the province. National Departments can investigate potential ways of supporting the development of implementation plans in the corresponding sector at the provincial level, and work with the National Treasury to assist the allocation of funds for the implementation of the corresponding sector strategies.

Similarly, Local Municipalities within the province are also urged to take cognisance of the recommended strategies and identify ways to integrate the strategies into their next Integrated Development Plans (potentially with assistance and guidance from SALGA). Business and industrial sector should identify and implement actions to reduce their carbon footprint. Academic and research institutions, non-governmental organisations and civil society have an important role to play in ensuring reduction in greenhouse gas emissions, adaptation to the inevitable climate change while ensure that essential resources are provided and used in a sustainable way within the Province.

Monitoring, reporting and evaluation processes will be central to demonstrating achievement of adaptation actions as they are implemented across all sectors, as well as supporting the ongoing review of the strategy to ensure the implementation of actions in the most cost-effective manner. As required by the National Climate Change Response Policy (2011), South Africa has recently designed a comprehensive National Climate Change Response Monitoring and Evaluation System (M&E System) that is coordinated by the National Department of Environmental Affairs, therefore the approach to monitoring and evaluation for this Strategy is aligned to and informed by the national M&E system.

Monitoring refers to a continuous process of examining progress made in planning and implementing climate change adaptation strategies. This might also include examining the context and environment within which adaptation occurs or drivers which shape resilience and vulnerability. The objective of monitoring can be described as being to keep track of progress made in implementing an adaptation intervention by using systematic collection of data on specified indicators and reviewing the measure in relation to its objectives and inputs, including financial resources.

Reporting, on the other hand, is the process by which monitoring and/or evaluation information is formally communicated, often across governance scales. It can enable the assessment of adaptation performance, and facilitate learning, on different scales, for example by providing an overview of progress across the province. Reporting on adaptation can be voluntary or a legal requirement, depending on the governance context or the reporting mechanism used.

Evaluation refers to a systematic and objective assessment of the effectiveness of climate change adaptation plan and actions, often framed in terms of the impact of reducing vulnerability and increasing resilience. Evaluations usually draw upon a range of quantitative and qualitative data, including those gathered through monitoring processes. Evaluations are undertaken at a defined point in the project or policy cycle. Ex ante and mid-term evaluations focus on ways of improving a project or programme while it is still happening. An ex post evaluation seeks to judge the overall effectiveness of an intervention, usually after a project or programme has been completed.

Once adopted, the Limpopo Provincial Climate Change Response Strategy will be monitored quarterly to determine progress against set targets. An annual progress report will be developed for stakeholders outlining achievements to date and reporting on any issues or change that may have occurred that will require minor adjustment to the plan. A major review will be undertaken in 2019/20 to identify future actions that may be needed to pursue climate change action.

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