Chapter 2

Environment, Climate Change and the Green Economy

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Abstract To identify and evaluate possible impacts of climate change on transportation in Limpopo province, it is necessary to define the scale and scope of the transportation system in the province and determine its sensitivities to climate change. This chapter, therefore locates the environment, climate change and the green economy matters in context. The science of climate change is explored, while the main sources of greenhouse gases are discussed. Additionally, the impacts of climate change in South Africa is outlined. Strategies to reduce greenhouse gas emissions (GHG) in the transport sector are provided.

Keywords Climate change · Transportation system · Green economy · Greenhouse gas emissions · Transport sector

2.1 Science of Climate Change

The United Nations Framework Convention on Climate Change (UNFCCC) in 1992 defined climate change as “**a change in climate which is attributed directly or indirectly to human activities that alter the composition of the global atmosphere and which are in addition to natural climate variations observed over comparable time periods**”.

Past climate variations are attributed to natural processes while the observed climate change is due largely to anthropogenic causes (Ogola et al. 1997). Climate change results from the increased emissions and subsequent concentration of gases such as methane (CH₄), carbon dioxide (CO₂), nitrous oxide (N₂O), chlorofluorocarbons (CFCs). These gases are referred to as greenhouse gases (GHGs) that form a cloud in the atmosphere due to human activities. They help to trap heat energy from the surface of the Earth, thus prevent heat from escaping into space (Fig. 2.1). Global warming results in shifts in weather patterns that lead to melting of icebergs

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Fig. 2.1 Global long term solar radiative balance of the atmosphere (IPCC 1995)

and sea-level rise, frequent hurricanes, impacts on water resources, agriculture, biodiversity, energy demands and other resources. The result is the effect on the quality of life with some species becoming extinct.

Awareness of climate change has been due to a number of initiatives that include:

- The Stockholm's Declaration of the United Nations Conference on Human Environment that took place in 1972;
- First World Climate Conference held in Geneva in 1979 by the World Meteorological Organization and the United Nations Environmental Programme, resulting in the creation of the World Climate Research programme;
- First Joint UNEP/WMO and the International Council of Scientific Unions (ICSU) held in Villach, Austria, in 1980 to initiate debate on a global convention and in 1985, the Group concluded that climate change and sea-level rise are closely related;
- Formation of the Intergovernmental Panel on Climate Change (IPCC) in 1988 and establishment of the three Working Groups: Working Group I on scientific analysis; Working Group II on impacts; and Working Group III on related legal instruments;
- United Nations Assembly in 1990 established the Intergovernmental Negotiating Committee (INC) to draft a Framework Convention on Climate Change (IPCC 1990);
- United Nations Conference on Environment and Development in Rio de Janeiro in June 1992, adopted the United Nations Framework Convention on Climate Change by the world community and it became known as the Climate Change Convention.
- The Kyoto Protocol was adopted in Kyoto, Japan, in 1997 and the purpose was for nations to agree to take action to address global warming. The treaty committed state parties to reduce greenhouse gas emissions;

- Johannesburg Summit 2002—the World Summit on Sustainable Development produced three outcomes: political declaration now known as the ‘Johannesburg Declaration on Sustainable Development’; the Johannesburg Plan of Implementation; and ‘Type II’ commitments by governments and other stakeholders, including business and non-governmental organisations;
- Paris Agreement (French: Accord de Paris) of 2015 is an agreement within the UNFCCC, dealing with greenhouse-gas-emissions mitigation, adaptation, and finance, starting in the year 2020, the agreement was negotiated by representatives of 196 state parties at the 21st Conference of the Parties of the UNFCCC and adopted by consensus, and the Paris Agreement’s long-term goal is to keep the increase in global average temperature to well below 2 °C above pre-industrial levels; and to limit the increase to 1.5 °C.

The development and improvement of the science of climate change involved a number of international programmes and projects that included:

- Global Environmental Monitoring System (GEM) sponsored by UNEP;
- World Climate Data Programme that provides information on the state of climate system and diagnosis of significant anomalies of regional and global sequence;
- Climate Change Detection Project, which regularly updates estimates of climate change on global and regional basis and assessing the relative importance of these change; and
- Global Climate Observation System (GCOS), which is intended to meet the needs for climate system monitoring, climate change determination and systematic observations of responses to climate change.

2.1.1 Sources of Greenhouse Gases

The main sources of greenhouse gases include energy use and production (57%), chlorofluorocarbons (17%), agricultural practices (14%), deforestation (9%) and others including industrial (3%). Burning of coal, oil and natural gas produces large quantities of CO₂, CH₄ and N₂O to the atmosphere. In South Africa, coal is the main source of electricity in the country, accounting for 79% in 2000 and 65.7% in 2006 (Fig. 2.2).

Carbon dioxide constitutes about 55%, methane-15%, nitrous oxide-6%, chlorofluorocarbons-11% and others-6% (IPCC 1990). Since the industrial age, about 200 years ago, the rate of CO₂ emissions to the atmosphere had increased steadily up to 1950, but after that the increase has been quite rapid (Fig. 2.3). This rapid increase of CO₂ to the atmosphere is largely attributable to energy use, especially in the transport sector.

Fig. 2.2 Primary energy supply in South Africa for the years 2000 and 2006 (Department of Minerals and Energy Annual Report 2009)

Fig. 2.3 Carbon dioxide emissions into the atmosphere since the industrial age (Letsoalo 2013)

2.2 Impacts of Climate Change in South Africa

South Africa has set two main objectives of dealing with the impacts of climate change (National Climate Change Response White Paper 2011):

- Effectively manage inevitable climate change impacts through interventions that build and sustain South Africa's social, economic and environmental resilience and emergency response capacity; and
- 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 climate change response objectives is based on risk reduction and management; mitigation actions with significant outcomes; sectoral responses; policy and regulatory alignment; informed decision making and planning; integrated planning; technology research, development and innovation; facilitated behaviour change; behaviour change through choice; and resource mobilisation.

The White Paper looks at the overall mitigation strategy that encompasses the following:

- Using a National GHG Emissions Trajectory Range, against which the collective outcome of all mitigation actions will be measured;
- Defining desired emission reduction outcomes for each significant sector and sub-sector of the economy based on an in-depth assessment of the mitigation potential, best available mitigation options, science, evidence and a full assessment of the costs and benefits;
- Adopting a carbon budget approach to provide for flexibility and least-cost mechanisms for companies in relevant sectors and/or sub-sectors and, where appropriate, translating carbon budgets into company level desired emission reduction outcomes.
- Requiring companies and economic sectors or sub-sectors for which desired emission reduction outcomes have been established to prepare and submit mitigation plans that set out how they intend to achieve the desired emission reduction outcomes.
- Developing and implementing a wide range and mix of different types of mitigation approaches, policies, measures and actions that optimise the mitigation outcomes as well as job creation and other sustainable developmental benefits. This optimal mix of mitigation actions will be developed to achieve the defined desired emission reduction outcomes for each sector and sub-sector of the economy by ensuring that actions are specifically tailored to the potential, best available solutions and other relevant conditions related to the specific sector, sub-sector or organisation concerned;
- The deployment of a range of economic instruments to support the system of desired emissions reduction outcomes, including the appropriate pricing of carbon and economic incentives, as well as the possible use of emissions offset or emission reduction trading mechanisms for those relevant sectors, sub-sectors, companies or entities where a carbon budget approach has been selected; and
- A national system of data collection to provide detailed, complete, accurate and up-to-date emissions data in the form of a Greenhouse Gas Inventory and a Monitoring and Evaluation System to support the analysis of the impact of mitigation measures.

2.3 Climate Change and Its Impacts on the Transport Sector

Between 2000 and 2010, the greenhouse gas emissions in South Africa increased by 27%, producing a total of accumulated greenhouse gases of 4,204,640 Gg CO₂ equivalent (Department of Environmental Affairs 2014). The main contributors of GHG emissions were energy sector (63.6%), predominantly from coal combustion to produce electricity (55.1%), followed by transport (10.8%) and manufacturing industries (9.8%) (Fig. 2.4). The transport sector contributes to greenhouse gas emissions through combustion of fossil fuels. Emissions are primarily from diesel and petrol consumption for road and rail transport and jet and aviation gasoline. This results in the release of CO₂ and to a lesser extent, CH₄ and N₂O.

In 2010, road transport consumption of fuel was about 91.2% and this resulted in greenhouse gas emissions of 92% of the transport sector (Department of Environmental Affairs 2014). Fuel consumption is by cars, light delivery vehicles, trucks, buses, trailers, tractors and motorcycles. Railway locomotives are of three types; diesel, electric and steam. The diesel locomotives use engines driven by diesel, while electric locomotives use electricity from power stations. GHG emissions from steam locomotives are currently negligible as their use is low. Civil aviation GHG emissions are due to combustion of jet and aviation gasoline. Aircraft GHG emissions constitute 70% CO₂, less than 30% water and 1% of other components (Department of Environmental Affairs 2014).

At a workshop in the USA on the impacts of climate change on transportation (Federal Research Partnership Workshop 2002) some of the outcomes of the workshop included recommendation on research on Coastal Regions/Marine (Table 2.1) so as to have a better understanding of the potential effects of climate change on ports and marine shipping due to storms, sea level rise, sedimentation and erosion

Fig. 2.4 Contributors to greenhouse gas emissions in South Africa

Table 2.1 Summary of research priorities—coastal/marine^a

Research challenge	Specific research needs
Storms and sea level rise	<ul style="list-style-type: none"> – Climate change effects on storm intensity, location, track – Clarification of projected trends – Exploration of local sea level changes and land movements – Simulation of storm events – Impact of sever events at different geographic scales
Sedimentation and erosion	<ul style="list-style-type: none"> – Impact on wave- and current-induced sedimentation – Changes to rainfall and river hydrology, sedimentation rates – Case studies at ports – Dredging disposal options
Changes in prevailing winds, waves, currents, and precipitation	<ul style="list-style-type: none"> – Improved monitoring, modelling – Relation to shipping, port design
Shipping routes	<ul style="list-style-type: none"> – Monitor extent and thickness of sea ice—Arctic and Great Lakes
Decision making and policy tools	<ul style="list-style-type: none"> – Improved models, elevation maps, GIS; communication tools
Socio-economic patterns, legal issues	<ul style="list-style-type: none"> – Localised land use, watershed, transport development trends

^aFederal Research Partnership Workshop (2002)

rates, and changes in key variables such as prevailing winds, waves, currents, and precipitation rates.

Focus was also made on coastal regions rail and road transport that focused on the effects of weather-related travel delays on rail and road system performance (Table 2.2).

As concerns the interior regions and their implications for surface transportation and pipelines the expert group focused on four priority research challenges (Table 2.3).

As summarised in the National Climate Change Response White Paper (2011), South Africa is vulnerable to impacts of climate change. According to the IPCC Working Group II (2014), there is a possible increase in temperature within Africa of over 2 °C by mid-century and this may reach 3–6 °C by the end of the century. This will be accompanied by heat waves and droughts in many parts of Africa. Coastal areas are likely to suffer from sea level rise and frequent storm surges. In the case of South Africa, it is predicted that by 2050, South African coastal area will warm up by 1–2 °C and by about 3 °C in the interior. By 2100, warming is projected to reach 3–4 °C along the coast and 6–7 °C in the interior. These high temperature increases will have adverse effects on the transportation system. Consequently, there will be need to have changes in construction and designs of transportation infrastructure

Table 2.2 Summary of research priorities—coastal/rail and road^a

Research challenge	Specific research needs
Weather related travel time delays	<ul style="list-style-type: none"> – Regional effects on transportation system performance – Travel behaviour response to delays
Impacts of climate change on roads and ecosystems	<ul style="list-style-type: none"> – GIS overlay of coastal roads and elevations—impacts of sea level rise on roads and habitat – Regional case studies of road design that minimise environmental impacts – Best practices for road construction and location
Smart growth	<ul style="list-style-type: none"> – Economics of coastal development and impacts of climate change – Analysis of anticipated sea-level rise and local development plans, using GIS technologies
Lack of public awareness of climate change consequences	<ul style="list-style-type: none"> – State and local case studies – Website development on potential climate change impacts

^aFederal Research Partnership Workshop (2002)

Table 2.3 Summary of research priorities—interior/rail, road and pipeline

Research challenge	Specific research needs
Tools to support local/regional scale impacts projection and decision making	<ul style="list-style-type: none"> – Service interruptions – Development of appropriate design parameters for new facilities – Integration of climate and impact models at comparable resolution – Data “info mining”
Hydrologic impacts on road, rail and pipeline infrastructure	<ul style="list-style-type: none"> – Evaluation of existing hydrologic models (under climate change scenarios) – Effects of hydrological changes on groundwater table/quality – Landslides/washout, flooding impacts on transportation facilities – Effects of sediment transport on infrastructure, and response strategies
Extreme events and impacts on roads, rail and pipelines	<ul style="list-style-type: none"> – Methods to characterise risks without complete reliance on historical data – Validation of climate, hydrological and impacts at multiple scales
Spatial and temporal shifts in demand	<ul style="list-style-type: none"> – Timing and location of shifts in transportation demand, relative to life of infrastructure – Impacts on port facility capacities and inter-modal flows

Fig. 2.5 Floods in Kwazulu Natal in 2017 (<https://www.news24.com/SouthAfrica/News/live-massive-storm-hits-durban-causes-flooding-chaos-20171010>)

and alternative sources of energy to mitigate against climate change. Transportation modes will have to be equipped with effective air conditioned facilities as daily minimum and maximum temperatures increase. Some of the impacts of climate change in South Africa have resulted in reduced crop yields due to prevailing drought in the country, increased coastal erosion, impact on tourism and loss of jobs, and interruption of transport systems, for example, the recent floods in Kwazulu Natal (Fig. 2.5).

In order to identify and evaluate possible impacts of climate change on transportation in Limpopo province, it is necessary to define the scale and scope of the transportation system in the province and determine its sensitivities to climate change. Transportation infrastructure is generally vulnerable to flooding and storm surges. Changes in precipitation patterns can put to risk the existing infrastructure in Limpopo province. Higher temperatures as have been experienced in 2015 and the earlier part of 2016 can pose risks to the existing infrastructure. Storm surges can also result in landslides as was experienced in the Vhembe district in the year 2000. Floods and landslides can affect the road and rail transportation network. This calls for a survey to identify valuable road sections in order to come up with mitigation strategies. Road tunnels like the Hendric Verwoerd tunnel between Louis Trichardt and Musina need to be monitored so as to prevent any potential calamities due to storm surges, floods and landslides or land subsidence.

In Limpopo province, changes in precipitation, soil moisture, groundwater regimes and flooding may put to risk both surface roads and railway network. This may call for the need to adjust engineering standards, location of infrastructure, maintenance of schedules, and safety management. Likewise, there could be need to

re-evaluate the existing hydrologic models to cope with the identified climate change scenarios. Risks due to potential changes in the frequency and intensity of extreme weather events will also require attention.

Mitigation strategies for the potential impacts of climate change in Limpopo province will have to address the following questions:

- (a) What are the most significant potential problems that climate change poses for transportation?
- (b) What are the priority research areas that require immediate intervention?
- (c) Are transportation planners equipped with the relevant tools that integrate climate change and impact models to support transportation decision making at the local and regional level?
- (d) Who should take lead on mitigation strategies as the issues at hand are inter-departmental?

The relevant tools for decision making include risk analysis information and the ability to translate impact findings to meaningful data for mitigation. Apart from broad issues, the study should focus on weather-related travel delays on the road and trail systems. Research on the effects of weather on travellers' response to adverse weather can help inform real-time operational and maintenance decisions of transportation managers. A better understanding of weather activity and its effects on surface transportation could support better planning and investment for long-term climate impacts (Potter 2002). This could result in best practices in road design and construction that respond to challenges of climate change.

2.4 Strategies to Reduce GHG Emissions in the Transport Sector

There is need to develop policies to reduce greenhouse gas emissions for a range of transport modes as well as the need to maintain the momentum towards a low carbon economy and towards decarbonising the transport sector through the use of alternative sources of energy that do not emit CO₂.

Whereas the Limpopo provincial mitigation strategies against climate change and environmental protection are well stipulated in the Green Economic Plan of 2013 and in the Strategy on Climate Change of 2016, the implementation is lacking. Strategies for extreme weather events fall within the docket of the Department of Disaster and Risk Management, but impacts affect all sectors of the economy, including the transport sector, thus there is need for coordination amongst the various departments. The environmental principle that "the polluter pays" is extremely difficult to monitor on site. What is being monitored is the ambient air quality and not gas emissions from individual sources. Development and utilisation of renewable energy sources is generally hindered by the powerful oil industry, vehicle manufacturers and transport companies. The perception that "the bigger the car the better" also hinders the development of the environmentally friendly vehicles.

2.5 Discussion

The main concern of the UNFCCC (1992) was that human activities have been substantially increasing the atmospheric concentrations of greenhouse gases, that these increases enhance the natural greenhouse effect, and that this will result on average in an additional warming of the Earth's surface and atmosphere and may adversely affect natural ecosystems and humankind. This led to the United Nations Conference on Environment and Development in Rio de Janeiro in June 1992 and the subsequent adoption of the United Nations Framework Convention on Climate Change by the world community and it became known as the "Climate Change Convention." Following this, was the Kyoto Protocol and the Conference of the Parties (COP) comprising UNFCCC participating member States. At the COP 21 meeting in Paris in December 2015, the member states adopted by consensus to reduce emissions as part of the method for reducing the greenhouse gas emissions. It looked at greenhouse-gas-emissions mitigation, adaptation, and finance, starting in the year 2020.

The long-term goal of the Paris Agreement is to keep the increase in global average temperature to well below 2 °C above pre-industrial levels; and to limit the increase to 1.5 °C, since this would substantially reduce the risks and effects of climate change (COP 21 2015). According to this Accord, each member state must determine, plan, and regularly report on the contribution that it undertakes to mitigate global warming. COP21 noted that in the first half of 2016 average temperatures were about 1.3 °C above the average in 1880, when global record-keeping began. The IPCC Working Group II (2014), however, noted that there is a possible increase in temperature within Africa of over 2 °C by mid-century and this may reach 3–6 °C by the end of the century. For South Africa, it is predicted that by 2050 the coastal area will warm up by 1–2 °C and by about 3 °C in the interior. The situation is likely to worsen by 2100 when warming is projected to reach 3–4 °C along the coast and 6–7 °C in the interior.

The described scenario above of temperature rise in general and for South Africa in particular calls for changes in construction and design of transportation infrastructure and alternative sources of energy to mitigate against climate change. There will be need to equip transportation modes with effective air conditioned facilities as daily minimum and maximum temperatures increase. Increase in intensity and frequency of precipitation will also result in floods and landslides, for instance, in Limpopo Province that will put at risk the existing transportation infrastructure. For example, in 2000 storm surges resulted in landslides in the Vhembe district and this led to landslides and destruction of houses.

Strategies to mitigate the impacts of climate change in the transportation sector include development of policies to reduce greenhouse gas emissions for a range of transport modes as well as the need to maintain a low carbon economy.

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